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#221 OCTOBER 2023

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Astronomy Photographer of the Year

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Welcome

October brings a rare ring of fire and a bite out of the Moon

This month, one of the most spectacular sights in all of nature will sweep across western USA and Central and South America. This 'ring of fire', an annular eclipse, is a special kind of solar eclipse during which only the outer edge of the Sun is visible, glowing dramatically (and brightly – eclipse glasses are needed to view). But what makes this eclipse different to a total solar eclipse? And how is the stunning ring effect created? Jamie Carter explains the remarkable cosmic coincidences involved on **page 72**.

There's an eclipse visible from the UK later in the month too. This one is of the partial lunar variety, when the full Moon will appear to have a bite taken out of it. Pete Lawrence has the details in the Sky Guide from **page 43**. You can also read there about comet 103P/Hartley, known as Hartley 2. This Solar System traveller reaches its closest point to the Sun this month, when it'll be at its brightest and should be interesting to observe.

All three events are surely worthy subjects for the Astronomy Photographer of the Year competition, which we're proud to announce the winners of in this issue. Turn to **page 28** to see all the dramatic prizewinning shots, selected from a starting field of more than 4,000 images sent in from 63 countries.

However, some things are simply beyond the reach of Earth-bound photographers, and on **page 60** Colin Stuart investigates the biggest mysteries of the Universe that still elude the greatest minds of cosmology. Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 19 October.

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

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New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Stuart Atkinson

Seasoned observer

"It's understandable if you always look at your favourite objects on a clear night, but explore the hidden alleys of the night sky now and again and you'll find some lovely sights." **Take a trip off the beaten track,** page 36

Govert Schilling

Astronomy writer

"Lava plains? Metal mountains? I'm looking forward to finding out what secrets asteroid Psyche holds, once the spacecraft of the same name reaches it before the end of the decade." **Read all about the new mission,** page 66

Anita Chandran

Science journalist

"It's extraordinary that scientists like Justin Spilker can detect the presence of tiny molecules in some of the most distant galaxies in the Universe, deeper into the past than we've ever looked before." **Find out more,** page 98

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/y8phiea** to access this month's selection of exclusive Bonus Content

OCTOBER HIGHLIGHTS

Interview: A magnetic Solar System

Michele Dougherty reveals how magnetic fields help in the search for habitable conditions beyond Earth.

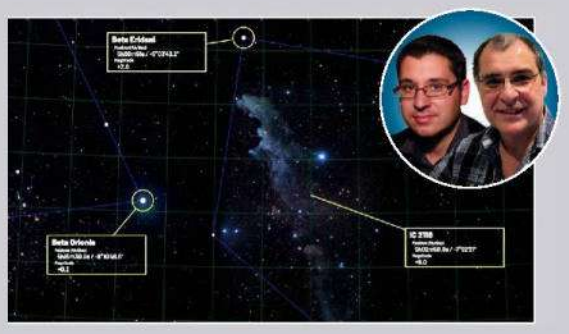
Black Holes: Searching for the Unknown

Watch this episode of *The Sky at Night* in which the team discover the secrets and the science of black holes.

APY 15: See all of this year's winning images

Browse all the images from 2023's Astronomy Photographer of the Year, including runners-up and highly commended.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

STEPPING INTO THE RING

JWST turns its attention to the Ring Nebula

JAMES WEBB SPACE TELESCOPE, 21 AUGUST 2023

The Ring Nebula, M57, has been a familiar sight to stargazers since 1779, when it was first observed by Charles Messier. But now, nearly 250 years on, new images from the James Webb Space Telescope have captured this old favourite in greater detail than we've ever seen before.

This picture was taken using the NIRCam instrument and shows that the planetary nebula's supposedly 'empty' central region is actually full of filaments of very hot gas. These, like the rest of the nebula, are remnants of the now-dying star that lies at its very heart, which will eventually become a white dwarf.

Then above is an image taken with JWST's MIRI instrument, revealing spikes and arcs in the nebula's outer regions, believed to be caused by interactions with a low-mass companion star.

MORE **ONLINE**

Explore a gallery of these and more stunning space images

ESA/WEBB/NASA/CSA/M. BARLOW/N. COX/R. WESSON

△ Busy Barnard

JAMES WEBB SPACE TELESCOPE, 31 JULY 2023

This image of NGC 6822, Barnard's Galaxy, shows how densely packed with matter galaxies really are. Combining data from JWST's NIRCam and MIRI instruments – which are good at imaging stars and regions of gas and dust, respectively – reveals just how much is going on in one of our nearest galactic neighbours.

△ Autumn leaves

JAMES WEBB SPACE TELESCOPE, 24 JULY 2023

Lying 210,000 lightyears away in the southern constellation of Tucana, NGC 346 is a region of intense star formation in the Small Magellanic Cloud, a dwarf galaxy that orbits our own Milky Way. This image, captured in the near-infrared by JWST's NIRCam, reveals a structure that resembles a leaf falling to the ground.

Sagittarian snowball ▷

VISIBLE AND INFRARED SURVEY TELESCOPE, 14 AUGUST 2023

This may look like a snowball hurtling through space, but it's actually an infrared image of NGC 6723, a globular cluster in the constellation of Sagittarius that lies about 28,000 lightyears from Earth. It's one of over 150 such clusters within the Milky Way, each consisting of up to a million stars.

NASA/ESA/CSA/STSCI/A. PAGAN (STSCI), ESO/S. MEINGAST ET AL, ESA/WEBB/NASA & CSA/M. MEIXNER , NASA/JPL-CALTECH

△ Flying saucer

SPITZER SPACE TELESCOPE, 21 AUGUST 2023

Spiral galaxies look very different when seen from the side: less like a whirlpool and more like the traditional shape of a UFO (or UAP, if you prefer). See, for instance, this sideways-on shot of NGC 4565, the Needle Galaxy in the constellation Coma Berenices, which was recently produced using archival infrared data from NASA's now-retired Spitzer Space Telescope.

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Why is there something rather than nothing?
Where is two thirds of the Universe?
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What is dark matter?
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FUTURE CITIES
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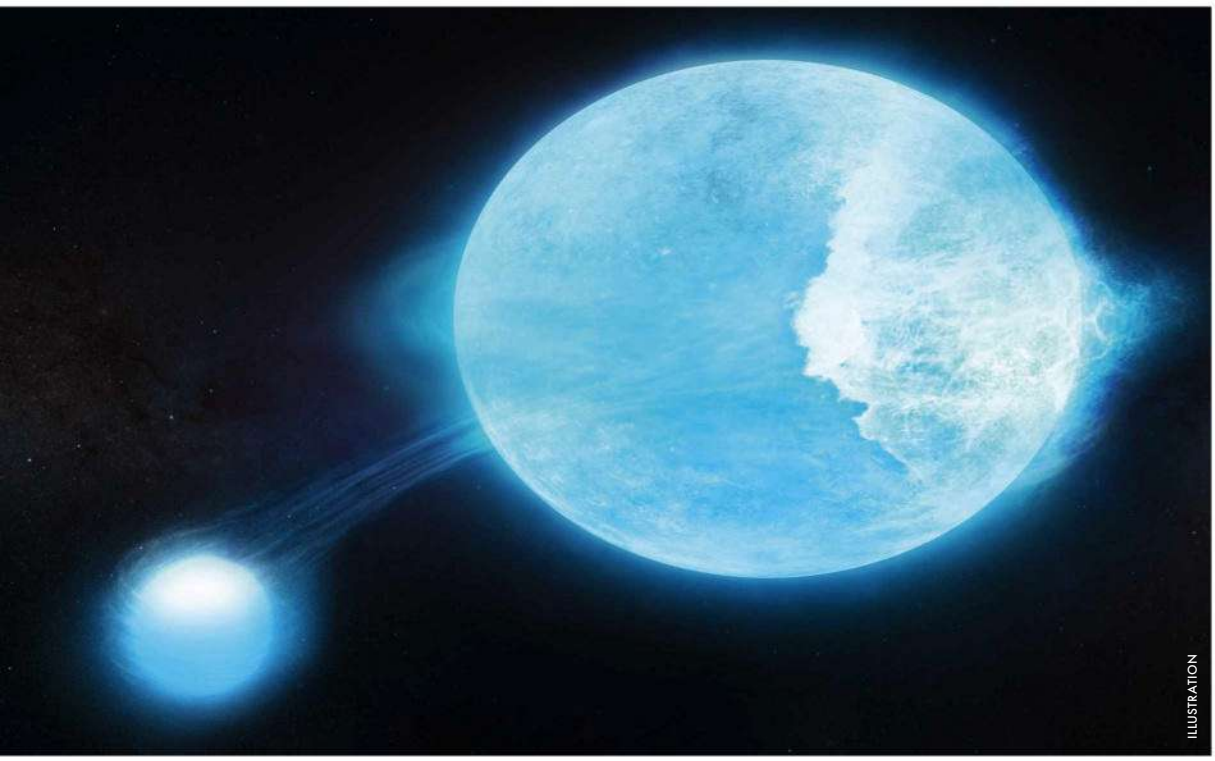
The latest astronomy and space news, written by Ezzy Pearson

BULLETIN



ILLUSTRATION

▲ **Surf's up: a small nearby star seems to be triggering giant tidal waves on massive star MACHO 80.7443.1718**

Colossal waves crash on stellar surface

A companion star could be creating breakers 4 million kilometres high

Stellar waves that tower as high as three Suns stacked on top of each other appear to be sweeping across the surface of a giant star, according to a new study.

The star is the most extreme known example of a 'heartbeat' star. These are pairs of stars locked in an elliptical orbit, where the gravitational pull of one distorts the other, elongating it. As the stars orbit each other, the angle we view them at changes. When the elongated side faces towards us the star looks brighter, while the compressed side appears dimmer.

In most heartbeat stars, the variance is only around 0.1 per cent of the total brightness. However, with this one, MACHO 80.7443.1718 – a 35-solar-mass star in co-orbit with a much smaller companion in the Large Magellanic Cloud – the brightness varies by 20 per cent, leading it to be dubbed a 'heartbreak' star. A new set of simulations, led by Morgan MacLeod at the Center for Astrophysics, Harvard & Smithsonian, may have found the reason behind the pair's fluctuations: colossal waves sweeping across the surface of the larger star, kicked up by the smaller companion. The waves are so tall and reach such speeds that they curl over at the top and break, much like waves in Earth's oceans.

"Each crash of the star's towering tidal waves releases enough energy to disintegrate our entire planet several hundred times over," says MacLeod. "These are really big waves."

Up to four million kilometres high, in fact, which is around one-fifth of the star's radius. The energy released by the crashes would cause the stellar surface to rotate faster, and hurls gas outwards, forming a cloud around the star.

"This 'heartbreak' star could just be the first of a growing class of astronomical objects. We're already planning a search for more heartbreak stars, looking for the glowing atmospheres flung off by their breaking waves," says MacLeod.

www.cfa.harvard.edu

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Comment

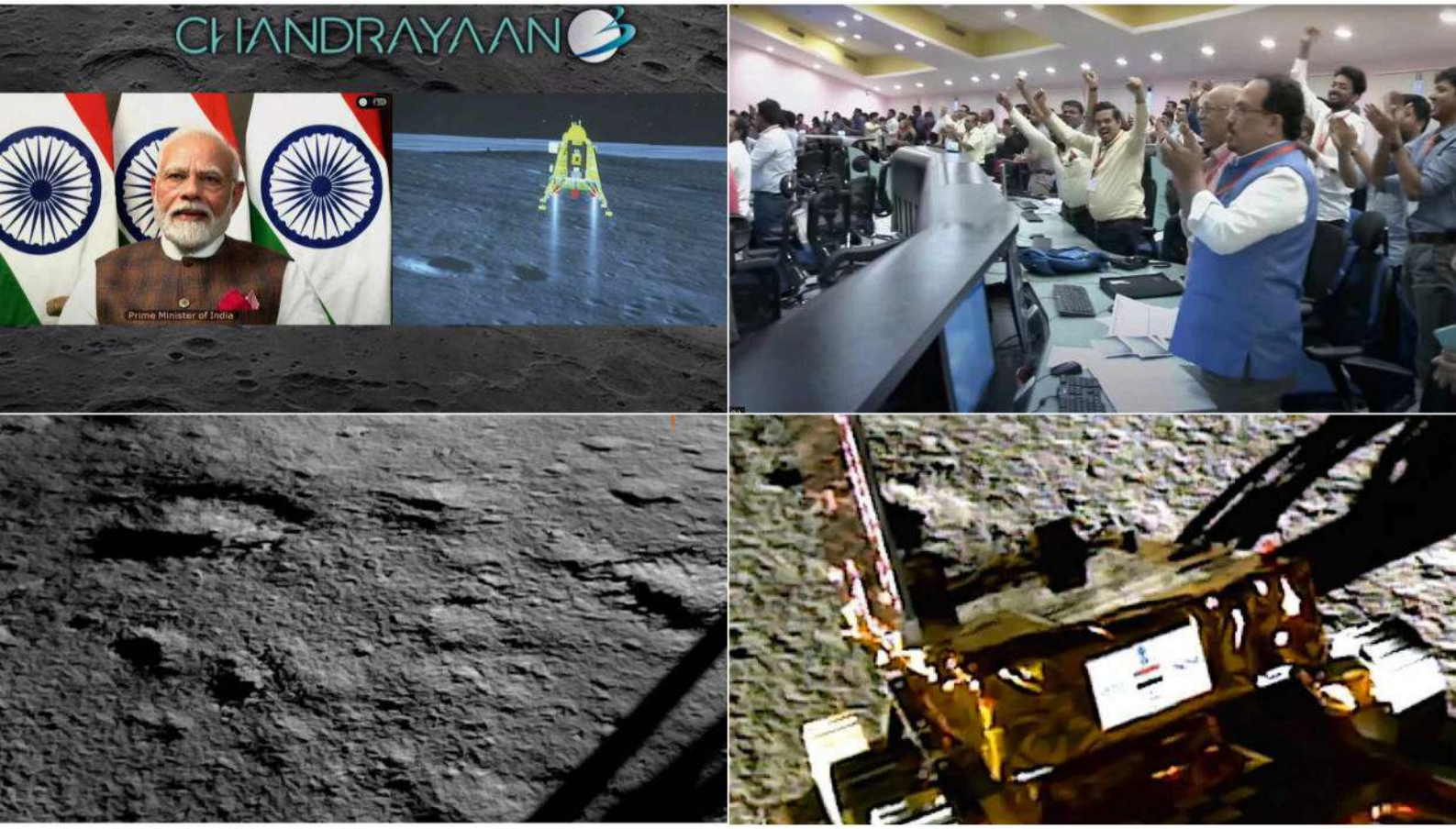
by Chris Lintott

I first found out about heartbeat stars when volunteers on our **Planethunters.org** project found a handful while looking through data from NASA's Kepler mission.

Modern missions that study hundreds of thousands of stars at once show that the range of behaviour we see is much larger than anyone imagined – all manner of pulsations, plenty of new types of extreme, cataclysmic variability and even dramatic events that resemble the sudden fading of Betelgeuse a few years back.

Understanding these changes will reveal, in detail, how stars really work. We may be 150 years on from the first systematic studies of variable stars, but they still have much to teach us.

Chris Lintott co-presents *The Sky at Night*



▲ **Top: Prime Minister Modi and the control room celebrate the landing. Bottom: the first images of the surface and the rover setting off**

India's Chandrayaan-3 lands at Moon's south pole

The achievement makes India the fourth nation capable of controlled landings on the Moon

Humanity has landed on the lunar south pole for the first time, after the Indian lunar mission Chandrayaan-3 touched down on 23 August. The mission was the Indian Space Research Organisation's (ISRO) second attempt to land on the Moon, after Chandrayaan-2 crashed into the lunar surface in 2019.

"Chandrayan-3 scripts a new chapter in India's space odyssey," says Indian Prime Minister Narendra Modi. "It soars high, elevating the dreams and ambitions of every Indian. India is now on the Moon. The sky is not the limit."

The mission's Vikram lander (named after ISRO founder Vikram Sarabhai) set down on the surface at 12:34 UT. After waiting several hours for the dust kicked up by the landing to settle, the lander deployed a ramp allowing its rover, Pragyan (Sanskrit for wisdom) to roll out onto the surface. The lander and rover are expected to operate thoughout the lunar day (14 Earth days). When lunar night falls the pair will be unable to charge their solar panels, however, and it is unclear if they will survive the darkness.

One of the mission's prime goals is to investigate the physical and chemical characteristics of the lunar surface in the region around the south pole. The pole has garnered much interest in recent years after ISRO's Chandrayaan-1 and NASA's Lunar Reconnaissance Orbiter uncovered evidence of water ice in the permanently shadowed craters found there. This water could date back to the very dawn of our planetary system and could reveal key insights into how both Earth and our Moon came to be. It is also a potential resource for future lunar explorers, and the site NASA has picked for its upcoming Artemis III human landing attempt, currently scheduled for 2025.

"Chandrayaan-3 is a mission that will take us one step closer to understanding the Moon and its mysteries," said ISRO chairman Sreedhara Somanath.

Several missions have attempted a landing at the lunar pole in recent years, including ISRO's own Chandrayaan-2, only to end in failure. Just a few days before Vikram's landing, the Russian space agency Roscosmos was preparing to put down their own Luna 25 mission in the region. However, on 20 August, the day before their landing attempt, the spacecraft lost control of its orbit and crashed into the lunar surface.

www.isro.gov.in

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The Galilean moons in a new light

JWST's infrared gaze gives a unique view of the moons

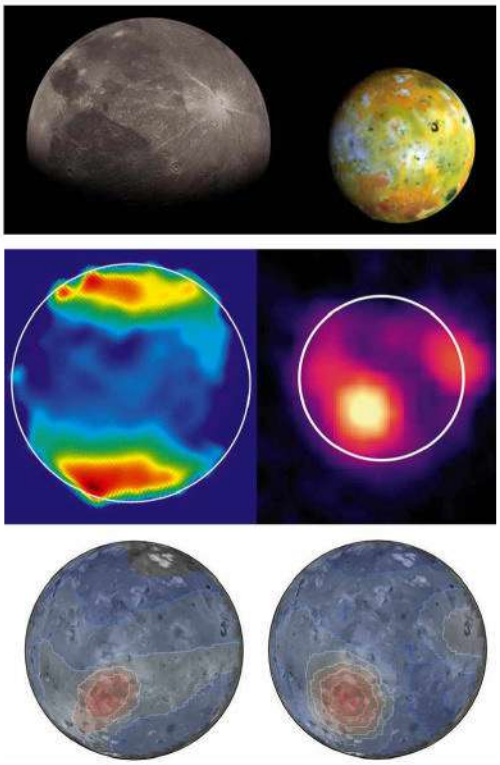
The latest JWST images of two of Jupiter's moons, Io and Ganymede, have revealed new secrets about these distant worlds.

Infrared spectroscopy of the icy moon Ganymede has revealed the presence of hydrogen peroxide around the northern and southern poles. The gas is created by the moon's magnetic field funnelling charged particles towards the surface where they strike the ice, breaking apart the water molecules. The fragments then reform as hydrogen peroxide, which has previously been seen around another of Jupiter's moons, Europa.

Meanwhile, JWST images of the volcanic moon Io show several known volcanic complexes had brightened in the infrared, suggesting ongoing eruptions. Astronomers were also able to link one of the eruptions to the emission of sulphur monoxide from the moon.

"This shows that we can do incredible science with the James Webb Space Telescope on Solar System objects, even if the object is really very bright, like Jupiter, but also when you look at very faint things next to Jupiter," says Imke de Pater from University of California, Berkeley, who is helping to lead the study.

news.berkeley.edu



▲ **Ganymede and Io (top left and right), the new spectroscopic maps (centre) and images of Io's volcanic zones (bottom) from JWST's data**

Red dwarfs pummel their planets

The intense flares of red dwarf stars bombard surrounding planets, stripping them of their atmosphere, but a new study has found the process could be far from smooth.

Red dwarfs' complex magnetic fields mean their stellar flares are 100 to 1,000 times more intense than those of our Sun and have a huge impact on the growth of surrounding planets. Researchers observing AU Microscopii, a youthful red dwarf with an infant planet orbiting it once every 8.5 days, were surprised to find no signs the planet was losing its hydrogen atmosphere. However, looking again 1.5 years later, they could see huge amounts of gas loss.

"We've never seen atmospheric escape go from completely not detectable to very detectable over such a short period when a planet passes in front of its star," says Keighley Rockcliffe from Dartmouth College.

One possible explanation is that the star's unpredictable magnetic fields cause extreme variability in the flares. Alternatively, stellar winds could be shaping the outflowing gas into clouds that don't appear in every observation.

"This observation is so cool because we're getting to probe this interplay between the star and the planet that is really at the most extreme," says Rockcliffe.

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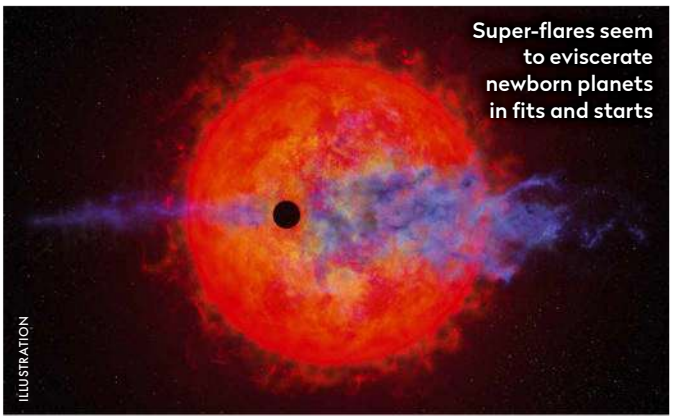


ILLUSTRATION

Super-flares seem to eviscerate newborn planets in fits and starts

NEWS IN BRIEF

ILLUSTRATION

Rogue Earths

The upcoming Nancy Grace Roman Telescope, due to launch in 2027, could find as many as 400 rogue Earth-mass planets which are not bound to a star. It's been estimated there could be trillions of planets in our Galaxy that have been ejected from their original star system and are now free-floating through space.

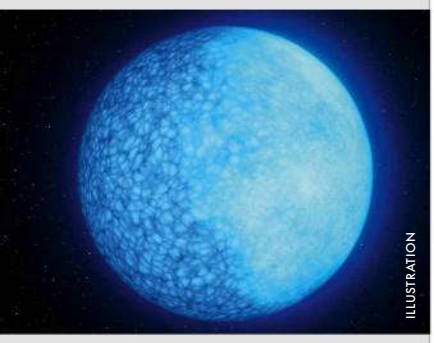
Milky Way's untwisted past

Our Galaxy may not have always been a spiral, according to a new study. Alister Graham from Swinburne University analysed over 100 nearby galaxies, finding indications that spiral galaxies could be a mid-stage of galaxy growth, rather than a starting point as had long been considered the case.

Streamlining UK launches

The House of Commons Science, Innovation and Technology Committee is calling for improvements to licensing for new UK space launches after Virgin Orbit's launch attempt in January was delayed by several months. It had struggled to get a licence from the Civil Aviation Authority.

NEWS IN BRIEF



ILLUSTRATION

Double-sided dwarf

Astronomers have discovered a star with a split personality – one side composed of hydrogen, the other of helium. The white dwarf, nicknamed Janus, spins on its axis every 15 minutes, allowing scientists to see both of its faces, though they are currently at a loss to explain how such a split came about.

Early galaxy has no dark matter

A massive galaxy dating from the earliest days of the Universe, NGC 1277, has been found to contain much less dark matter than our current understanding of galaxy growth predicts, a process in which dark matter was thought to play a pivotal role.

Neptune's clouds follow the Sun

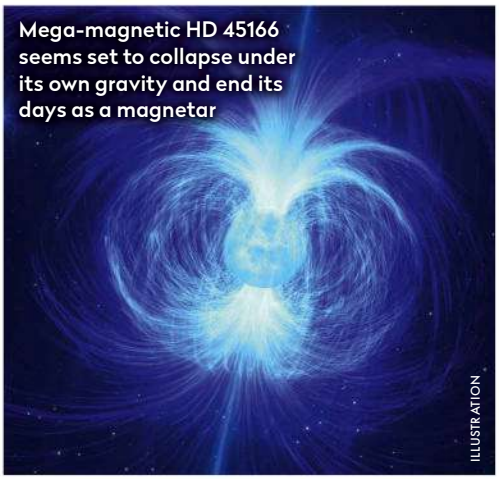
Despite only receiving one per cent of the sunlight seen on Earth, the weather on Neptune could be significantly affected by the 11-year solar cycle. Looking back over 30 years of Hubble data, astronomers have found that the abundance of clouds on the planet appears to wax and wane following a similar timescale.

K. MILLER/CALTECH/IPAC, ESO/L. CALÇADA, NASA/JPL-CALTECH/MSSS/IRAP

BULLETIN

Mysterious star points to magnetar origins

Never-before-seen example may reveal source of ultra-magnetism



Mega-magnetic HD 45166 seems set to collapse under its own gravity and end its days as a magnetar

ILLUSTRATION

The ultra-magnetic remains of dead stars – known as magnetars – are the most powerful magnets in the Universe, but their origin has long been a mystery. That could soon change, however, thanks to a recent set of observations of a mysterious helium-rich star.

HD 45166 is around two times more massive than our Sun, but its unusual behaviour has defied explanation. That was until Tomer Shenar from the University of Amsterdam realised it could be highly magnetic, something not normally seen in massive helium-rich stars. Using telescopes from around the world, Shenar and his team discovered the star had a magnetic field of 43,000 Gauss (for comparison, our Sun is around 1 Gauss).

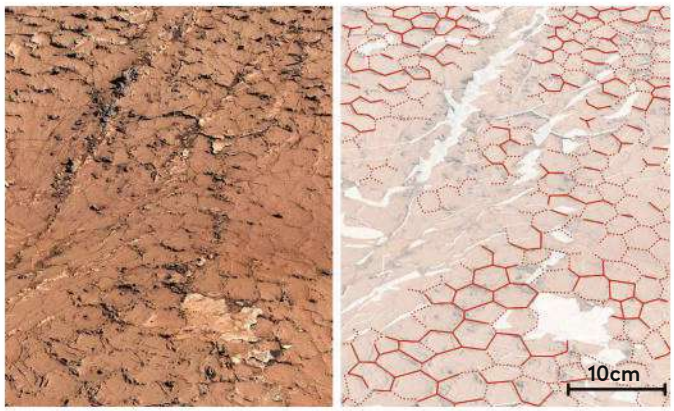
"The entire surface of the helium star has a magnetic field almost 100,000 times stronger than Earth's," says Pablo Marchant from KU Leuven, who took part in the study.

The team predict that when the star reaches the end of its life it will collapse to form a neutron star. This will compress its magnetic field, raising it to around 100 trillion Gauss, which would make it a magnetar. **www.eso.org**

Martian seasons may have helped life emerge

The Curiosity rover has found evidence that ancient Mars experienced a cyclical climate similar to that of Earth's seasons, potentially increasing the planet's past habitability.

Though Mars is now an arid and dry place, liquid water did once flow across its surface. Observations taken by NASA's Curiosity rover in a region believed to have once been a lake show deposits of salt which were laid down 3.6 to 3.8 billion years ago, and which are marked with a ridged pattern of hexagons. On Earth, similar patterns are created in basins that dry out seasonally, suggesting Mars experienced wet and dry seasons in the past.



▲ **Mud cracks suggest Mars once had recurring wet–dry weather cycles that may have created the conditions for life to emerge**

Water is one of two ingredients necessary for the emergence of life (at least as we know it) found on Mars. The other is organic molecules which form the building blocks of life. Curiosity and sibling rover Perseverance have both found several simple organic molecules, but for life to emerge these must first arrange themselves into more complex forms, such as RNA.

One way this can happen is by repeatedly changing the concentration of the chemicals in water – something that happens in areas which dry out seasonally, meaning such salt flats could have once been the breeding ground for emergent Martian life. **www.cnrs.fr/en**

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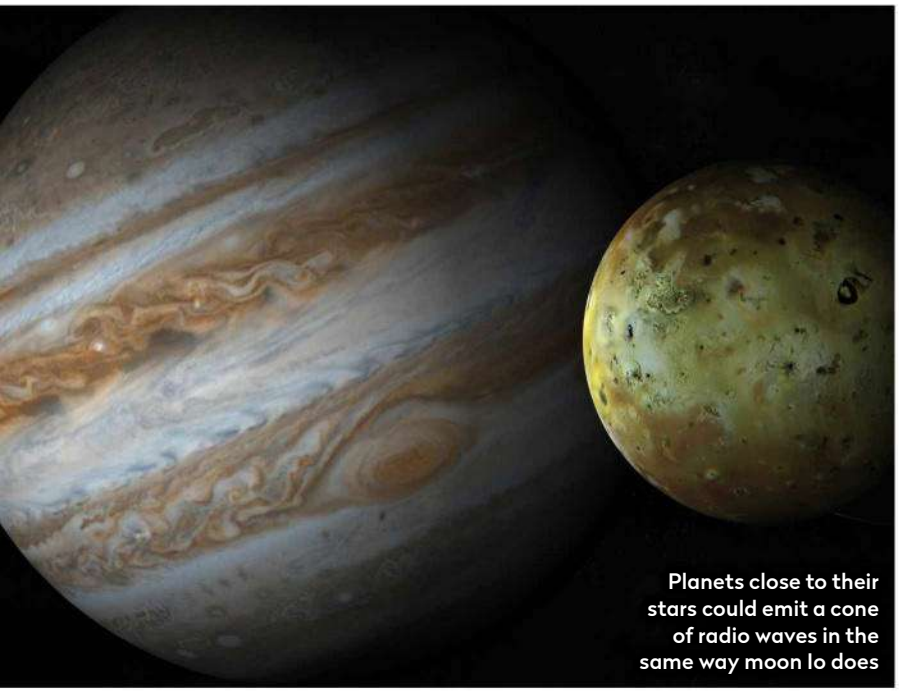
CUTTING EDGE



Planets close to their stars could emit a cone of radio waves in the same way moon Io does

IANM351STPOCK/GETTY IMAGES, © 2023 ATLAS OBSCURA

A novel way to detect unseen worlds

Jupiter and Io's interactions inspired a new method for finding exoplanets

Exoplanet hunters have a number of different ways of detecting worlds around other stars in the Galaxy – such as observing how the star is tugged around slightly by the orbiting planet's gravity, or its starlight being partially blocked by a transiting planet. But how else might astronomers be able to indirectly infer the existence of an unseen planet around a star?

One idea that's been floating around for a little while now is the possibility of detecting exoplanets by the radio waves emitted through magnetic interaction between the star and planet. The underlying process is well known for Jupiter and its moon Io. As Io orbits around Jupiter and through its powerful magnetic field, charged particles from the moon are swept towards the planet in what's known as an Alfvén wave, which in turn accelerates a stream of electrons that emit a cone of radio waves.

Astronomers propose that the same physical process could be used to detect planets close-in around their star. Small, red M-dwarfs would be excellent candidates to check because such stars generally possess strong magnetic fields. Encouragingly, a number of M-dwarfs have been discovered to give off bright radio emissions characteristic of what would be expected from magnetic star–planet interactions – although other mechanisms have not yet been ruled out – but none of the stars harbour any known close-in planets.

The trick for such a planet-hunting method is that the radio waves are emitted in a beam that sweeps through space as the planet orbits, and so you'd need to be listening with a radio telescope at the right moment to pick up the emission. For Io and Jupiter, within the plane of our own Solar System, the orbital, rotational and magnetic axes are all lined up with each other, and perpendicular to our line of sight from Earth. This neat configuration means that we detect a burst of radio emission when Io is at an orbital phase of 0.25 and 0.75 – that is, when the moon is moving directly towards or away from us in its orbit around Jupiter, so that the cones of radio emissions are angled towards Earth.

"As Io orbits Jupiter, charged particles from the moon are swept towards the planet in what's known as an Alfvén wave"

But for exoplanetary systems, the orbital, rotational and magnetic axes within the star–planet system are not likely to be so conveniently aligned. Robert Kavanagh and Harish Vedantham at the Netherlands Institute for Radio Astronomy have been investigating when such radio emissions are most likely to be detectable, and what would be the best survey strategy to pick them up from different planetary systems. Their computer modelling indicates that the easiest planetary systems to detect using this radio method are those orientated nearly face-on to Earth. This is useful because many of the other planet-detecting techniques, such as transit or radial velocity, are most sensitive to planetary systems lying edge-on to our line of sight. In fact, as Kavanagh and Vedantham point out, this could be the very reason why no close-in planets have yet been discovered around any of the M-dwarfs found to be producing the suggestive radio emissions.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Hunting for Exoplanets via Magnetic Star–Planet Interactions: Geometrical Considerations for Radio Emission* by Robert D Kavanagh and Harish K Vedantham
Read it online at: arxiv.org/abs/2307.02555

Touching the night sky

3D maps could reveal the cosmos to more people than ever before

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

I love it when people get in touch to tell us what they enjoy about recent *Sky at Night* programmes, and one of the most voluminous e-mailbags was when we featured the work of Portsmouth's transformative 'Tactile Universe' project. Led by astronomer Nic Bonne, who happens to be visually impaired, the team have pioneered 3D printing of data from the world's best telescopes – Hubble images of galaxies, for example – in a form that can allow them to be appreciated by touch.

It's an excellent example of creative thinking, bringing the wonders of the Universe to new audiences, but necessarily limited, for now, to educational use, not research. Each set of models, calibrated so that differences in colour can be perceived in comparing data taken through different filters, takes hours or even days to print – not much good if you're hoping to monitor what's happening in the sky direct from the 'scope.

Some astronomers have been thinking about sound as a possible solution. Innovative sonifications transform what would normally be visual data into sound, both for fun and for accessibility. We memorably used just such a piece at the end of our epic programmes covering ESA's Rosetta mission, when we broadcast a sonified version of the spacecraft's plasma data as 'the song of the comet'.

More than meets the eye

Using such tools in research is still far from common, though. I remember the lead author of this month's paper, Wanda Díaz-Merced explaining at a meeting that this is partly because we do not all learn to hear in the same way as we learn to look at data, but it does highlight the need for new techniques.

Anyone who has looked through an eyepiece or stared at an image knows that there can be meaning in what seems at first to be 'noise', and in subtle changes that the eye only just catches. Working with collaborator Ruoning Lan, Díaz-Merced has developed a system that might be the beginning of experiencing such features not through the eyes, but through touch.

The setup seems simple. A programmable Arduino circuit board is attached to a sensor, which is added to a small telescope. It, in turn, talks to a haptic device – a pad of pins which can be raised or lowered by a set of motors in response to its input, and this can be felt by the user.

Getting the system to work in real time is extremely difficult. So far, in this proof-of-concept paper, it is the light of the Moon which triggers the device – a beginning, but also the first time that data from a live telescope has been 'displayed' in this way.

To show its potential, the team also used the haptic device to allow a user to explore data from a chronograph, monitoring the Sun during a coronal mass ejection. Excitingly, they were able not only to detect the explosive outburst from the Sun, but through the haptic device were able to map its intensity and hence measure its mass.

"Excitingly, they were able not only to detect the coronal mass ejection, but through the haptic device were able to map its intensity"

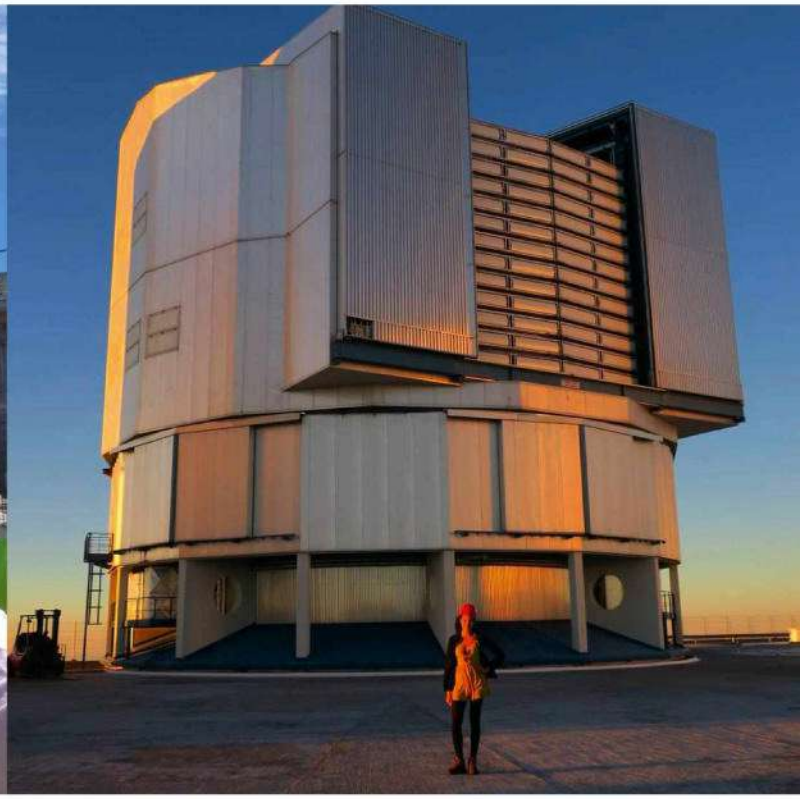
Such experiments can only be the start. But maybe they show that one day we will all be able to *feel* the sky – and that could soon include those who currently find it difficult to see what our shared telescopes are showing us about the cosmos.

▲ **Sonification expert Díaz-Merced aims to create a device that translates cosmological data into experiences that users can see, hear and feel**

Chris Lintott was reading... *Touching the Sky: The Use of Arduino in Transferring Telescopic Light to Haptic Vibrations* by Ruoning Lan and Wanda Díaz-Merced **Read it online at: arxiv.org/abs/2308.00657**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



In September, *The Sky at Night* met **Abigail Frost** who helps operate the telescopes at the Paranal Observatory in Chile. She tells us about her job

The moment I arrived at Paranal Observatory, I knew I didn't want it to be my only visit. A fresh-faced PhD student only a couple of months into my studies, I had the opportunity to travel from the University of Leeds to collaborate with the astronomers in charge of operating the telescopes at the top of Cerro Paranal in the Atacama Desert, northern Chile. ESO now operates eight telescopes at the observatory under the umbrella term 'The Very Large Telescope' (VLT), and an additional survey telescope, VST, at the site. Thanks to the extreme dryness of the Atacama and the observatory's remote location, Paranal Observatory has established itself as a world leader in studying our Universe at optical and infrared wavelengths.

Fast forward eight years since I first set foot at Paranal, and living and working at the observatory is now a core part of my job. For 105 nights of the year, I'm out in the desert, taking observations from the observatory control room for astrophysicists all over the globe. Working in such a remote place, and a desert to boot, takes some adjustment – if you didn't have a skincare regime before arriving, you make one! That being said, the 'residencia' where the engineers, caterers, administrative staff, astronomers and more all live and work is a welcoming and special community. Movie nights, sports facilities, the pool, sauna and music room mean there's always something you can do to relax after or before your daily work, and many of us make use of the stunningly dark skies to get into astrophotography. Visitors are common too, with politicians, actors, musicians (and now *BBC Sky at Night*!) passing through. Since my interest in astronomy was sparked during my childhood in the UK, being able to talk to Dr Maggie Aderin-Pocock about my work as a career astronomer felt like a wonderfully full-circle moment.

During and since my PhD, I have worked with data taken at Paranal Observatory, using a technique called 'interferometry' to combine the light from different telescopes simultaneously to get a detailed, unique view of massive stars, which will form supernovae and black holes, and the natal, dusty, nebulous cradles where stars are forming. I started working at the observatory in February 2023 as an

▲ Right: Abigail outside the Paranal Observatory which sits above a Martian-like, rusty-red desert landscape in northern Chile. Left: at the nearby construction site for the Extremely Large Telescope

ABIGAIL FROST, ESA/MPAE LINDAU, BBC

Abigail Frost is an operations staff astronomer at the European Southern Observatory in Chile

operations staff astronomer, which means I split my time between doing my own research and supporting the operation of the observatory. Collaborating with engineers, telescope operators and more has given me a whole new view of the data and the telescopes I work with. It prompts me to think about my research in new ways and inspires me to expand my methods.

ESO is planning expansion too, with its next project, the Extremely Large Telescope (ELT), half-completed and *literally* on the horizon from Paranal Observatory. The dome structure is now clearly visible on the top of Cerro Armazones, just a short drive from the VLT. This new telescope will be the largest ever built, eclipsing all current telescopes in size, including the recently launched JWST. With a primary mirror 40 metres in diameter, five times bigger than what has previously been available, the view we will get of the Universe will be revolutionised. When visiting the ELT construction site shortly after I returned to Chile to start my staff position, I couldn't help but get the same feeling of excitement as the first time I arrived at Paranal. The future of astronomy is bright. In another eight years, I'm looking forward to stepping into a completely new observatory in the form of the ELT, and into a new chapter of understanding the Universe as an astrophysicist.

Looking back: The Sky at Night

18 October 1986

In *The Sky at Night* on 18 October 1986, Patrick had the honour of revealing a close-up image of a comet's nucleus for the first time on television. Throughout the year, the show, and the world, had been following the progress of Halley's Comet as it returned to the inner Solar System for the first time since the dawn of the Space Age.

▲ Giotto's close-up of the nucleus of Halley's Comet taken on 13–14 March 1986

With several space agencies keen to take advantage of the opportunity, a fleet of spacecraft known as Halley's Armada were racing to visit the comet. The Soviet Union sent two Vega probes, while Japan sent their own Suisei and Sakigake probes. But it was the European Space Agency's Giotto that made the closest approach to the comet, flying past on 13–14 March 1986 at a speed of 245,000km/h. It came within just 596km of the comet, close enough to fly through the cloud of ice and dust which made Halley's glorious tail. When Giotto was just 7.6 seconds from closest approach, it was stuck by an ice fragment. Though this weighed only a gram, the huge speed was enough to send the spacecraft spinning.

Giotto was able to stabilise itself and transmit its observations to Earth. Over the following months, its data revealed the comet was 80 per cent water and 10 per cent carbon monoxide, with the remainder a mix of hydrocarbons. It also sent home a black and white image taken from just 1,917km away – our first-ever view of a comet's nucleus, the mysterious visitor's frozen heart.

The Sky at Night: Question Time

This year's annual *Sky at Night* Question Time is coming from Exeter University as part of the British Science Festival. Join host Dallas Campbell and an expert panel featuring the *Sky at Night* presenters Maggie Aderin-Pocock, Chris Lintott and Pete Lawrence, alongside special guests who will be answering all your questions on astronomy and space science.

BBC Four, **9 October,** 10pm
(first repeat will be on BBC Four, **12 October**, 7pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ Join Dallas Campbell, the *Sky at Night* presenting team and a panel of experts for an hour-long special Question Time

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

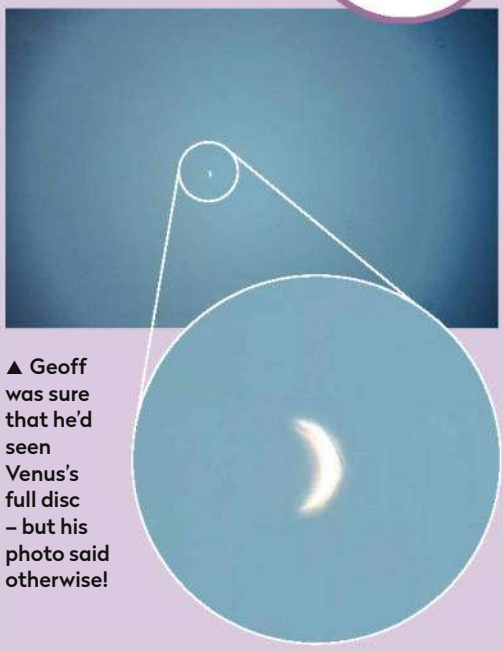
This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2024* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Now you see it...

In your excellent recent Virtual Planetarium video, Pete Lawrence and Paul Abel revealed night-sky highlights in July. They talked about viewing the crescent Venus, especially in daylight. One feature they debated was whether it's possible to 'see' the outline of the whole planet when it's in its crescent stage, pondering if it is truly something you see or something your brain does for you – sort of like completing the picture because it knows there is a full disc there. Well, I managed to image Venus through my Celestron 8SE telescope recently, and I was sure I could make out the full disc visually at the time. But zooming in on the photograph I took, it clearly wasn't visible – my brain was working overtime!
Geoff Winterman, Pembrokeshire



▲ Geoff was sure that he'd seen Venus's full disc – but his photo said otherwise!

What a fascinating observation, Geoff. It seems that Venus's Ashen Light has eluded the cameras once again! You can keep up to date with observing highlights each month in our Virtual Planetarium. Find it on our YouTube channel at **youtube.com/@bbcskyatnightmag** ***– Ed.***

Tweet

Ollie Aplin
@carefreeastro • 23 August
The Rotten Fish & Dark Shark
A pair of nautical nebulae imaged over 10 moonless nights, mosaicked together from 30 hours of exposures. The fish definitely drew the short straw on the naming...
@skyatnightmag

ET's view of Earth

If a being or alien was looking at our planet from, say, 150 lightyears away, would it be looking at Earth in its future or in its past? I have been watching Chris Packham's *Earth* series on BBC iPlayer and was fascinated to learn of all the incredible changes our planet has experienced over the billions of years of its existence. Could the alien see the world as a snowball, or a blue planet or any other manifestation?
Judith Sutcliffe, Kidderminster

Interesting! Assuming an intelligent being 150 lightyears away was looking at Earth right now, the light it would be seeing would have left our planet 150 years in the past. And, theoretically, yes, if a being 600 million lightyears away could somehow make out our planet, at the present moment it would be seeing light that left our planet when it was a Snowball Earth. ***– Ed.***

Satellite scourge

As a recent subscriber to *BBC Sky at Night Magazine*, I was particularly hooked on the article 'The new Space Age' (April 2023 issue, page 60). The section titled 'Growing anxiety about satellites' really got me thinking deeply about how polluted our sky will potentially be when more megaconstellation satellites are launched to low-Earth orbit – estimated to be 10,000 by the end of this year.

I live on a very remote island in western Scotland where the skies are pitch black, and last night was no exception. I headed out with my binoculars and within 45 minutes I had seen eight or nine satellites flying across my field of view. It really brought home to me that even in my corner of Scotland, these satellites are still very noticeable.
Kirsty Wright, via email

After getting this lovely shot of Cygnus, Dean can't wait to get back under dark skies

Dark devotee

To date, I have taken all my astrophotos from my back garden, which have all been affected by local light pollution in some way. But I finally got an opportunity to take an astrophoto under dark skies (above) while camping in August, capturing Cygnus including Deneb and the North America Nebula through the treetops in Wimborne, Dorset, with my Nikon D200 DLSR, 35mm lens and Sky-Watcher Star Adventurer 2i tracking mount. The difference under dark skies is quite incredible and I would recommend any beginner astrophotographer who has yet to visit a dark-sky area to try it at some stage. The experience has made my back garden not quite as appealing a location now, and I'll be looking to travel further to get my astrophotos again!

Dean Noonan, Fareham

Flats chat

I have just received the September issue of the magazine and was drawn to Charlotte Daniels's article on flat frames (Astrophotography Processing, 'Mastering flats', page 78). The article seems to suggest using the Sun as a light source, with the lens covered with a white T-shirt as one method of capturing flats, but I am of the opinion that optical systems shouldn't be pointed anywhere near the Sun without proper solar ▶

ON FACEBOOK

As we reported on India's Chandrayaan-3 landing on the Moon, many of you posted your messages of congratulation

Mohakash Milan India's historic moment! Congratulations from Bangladesh!

Carl Sharpe Congrats, fantastic achievement!

John Evans Well done India, proving that complex things can be done on a low budget. India are a long way behind China on space exploration, but given time and money they can catch up.

Adrian Pink Congratulations India.

Matthew Terrell Great news. A fantastic effort by all. Well done.

Victoria Smethurst Congratulations to them all, just watched the live stream.

Andrew Tudor What an exciting and beautiful achievement. The boundaries of science pushed again. Time to be proud.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

Can you suggest a low-cost tripod and mount for my Vixen VMC110L telescope that I can leave set up in my grandson's garden, where the skies are darker?

TONY JENKINS

STEVE RICHARDS

▲ Long focal lengths call for a stable mount to avoid vibrations. Vixen's Porta II is a good option

The Vixen VMC110L is a modified Maksutov-Cassegrain telescope that dispenses with the large and heavy meniscus lens at the front of the telescope in favour of a small correcting lens in front of the secondary mirror. This optical arrangement produces a focal ratio of f/9.4, yielding an effective focal length of 1,035mm, making it most suitable for lunar and planetary observations.

Although this telescope is quite short in physical length, its folded light path design produces a relatively long focal length, so a solid mounting is vital to produce vibration-free observations. There are several low-cost mount/tripod combinations that would be suitable.

For a completely manual option, Vixen's own Porta II altaz mount and tripod would be excellent, or the Sky-Watcher AZ4 altaz mount with either the steel or aluminium tripod would be a cheaper alternative with a similar maximum payload. For a low-cost Go-To mount, the Sky-Watcher Star Discovery WiFi AZ Go-To mount and tripod should also be on your shortlist.

Steve's top tip

What does a neutral-density filter do?

Observing bright celestial objects like the Moon can be quite tiring on the eye as the large aperture of a telescope collects an enormous amount of light, which can sometimes be difficult to adapt to. An overly bright object will also suffer from a loss of contrast which makes it more difficult to discern fine detail. The solution is to use a neutral-density filter, which reduces the available light by a set percentage but affects all wavelengths equally to ensure that it doesn't impart a colour cast. Neutral-density filters are available in various strengths, but an ND4 (also known as 0.6) filter would be a good starting point.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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EDITORIAL
Editor Chris Bramley
Content Editor Iain Todd
Features Editor Ezzy Pearson
Art Editor Steve Marsh
Production Editor Jane Williamson
Reviews Editor Paul Money

CONTRIBUTORS
Stuart Atkinson, Melissa Brobby, Jamie Carter, Anita Chandran, Charlotte Daniels, Lewis Dartnell, Glenn Dawes, Russell Deeks, Mark Garlick, Chris Grimmer, Tim Jardine, Pete Lawrence, Chris Lintott, Mathew Ludgate, Jonathan Powell, Katrin Raynor, Steve Richards, Colin Stuart, Steve Tonkin, Jenny Winder, Emily Winterburn

ADVERTISING SALES
Advertising Executive Andy Williams
+44 (0)117 300 8803, Andy.Williams@ourmedia.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Hannah Gazzard
Ad Services Manager Paul Thornton
Ad Coordinator Charles Thurlow
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
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Head of Marketing Jacky Perales-Morris
Marketing Executive Kellie Lane
Press and PR Manager Emma Cooney

PUBLISHING & MANAGEMENT
Associate Publisher Rob Brock
Managing Director Andrew Davies
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BBC STUDIOS, UK PUBLISHING
Chair, Editorial Review Boards Nicholas Brett
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Compliance Manager Cameron McEwan
UK.Publishing@bbc.com; www.bbcstudios.com

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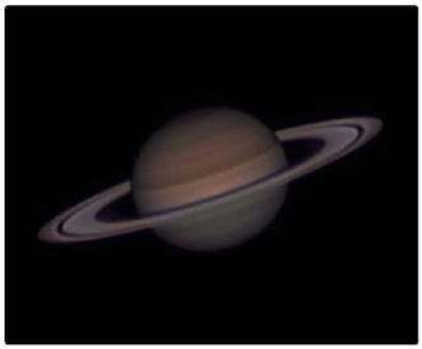
Instagram

erics.back.yard.stars • 28 August

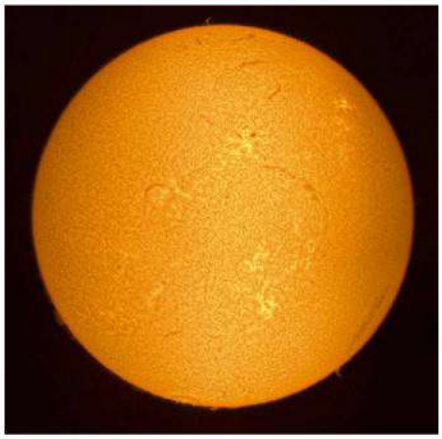
The weather cooperated enough to get a couple of opposition images on the table. These are probably some of the best Saturn images I've been able to capture! Images captured using my 14-inch Skywatcher 350P DOB GoTo with a ZWO ASI662MC planetary camera #saturn #space #planets @bbcskyatnightmag



▶ filters in place. I use a clean sheet of A4 printer paper in an evenly lit room to capture flat frames, or the white T-shirt method and point the scope at a clear area of sky well away from the Sun, and both these methods work well for me.
Kevin Rudd, via email

Golden oldie

Here is a full-disc image taken with my old double-stacked Coronado PST. The beauty of this solar telescope is that it can be taken out quickly, which has proven itself invaluable this summer with the fleeting gaps in the cloud cover! I use a ZWO ASI178 mono camera with SharpCap to capture data. Further processing with AutoStakkert! and GIMP have refined the data, resulting in the image here. I should also express my gratitude to this magazine for showing the way forward in my astrophotography journey!
Anton Matthews, via email



▲ Anton made the best of a rare sunny day thanks to his trusty PST solarscope

SOCIETY IN FOCUS

Almost since its inception, the focus of **Sunderland Astronomical Society** (SAS) has been outreach, with particular emphasis on the young. Our facility at the Washington Wetland Centre provides lecture space and the location for our two main observatories. While the sky at this location is at best Bortle 6, it has nonetheless proved adequate for outreach, and we've had many visits from local Scouts and youth groups.

The society supports other local events across the North East, including a recent solar event at North Tyneside's Northumberland Park and stargazing at St Mary's Lighthouse.

We run talks throughout the year on the third Sunday of each month. Covid brought the use of Zoom to the fore and for several months this was the only way we could continue. We've now returned to the Wetlands facility, but talks remain available on Zoom for those who need it.

▲ Chairman Chris Duffy tests out the new iOptron mount inside the society's dome

Recent investments include the purchase of an iOptron CEM120 mount on which is mounted a Sky-Watcher Esprit 150mm apo refractor. We also added a 12.5-inch Heritage Newtonian installed in a purpose-built wooden OTA and Dobsonian mount, and we've ordered a ZWO Seestar S50 'smart telescope' too.

We meet every Thursday and Sunday evening and welcome members of the public interested in observing through the society's telescopes.
David Ettie, SAS committee member
▶ www.sunderlandastro.com

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Introduction to Astrophotography

Online, Tuesdays from 31 October, 7pm

If you'd like to get started in night-sky photography, this six-week beginners' course hosted by the Royal Observatory, Greenwich could be just what you need. With sessions held via Zoom every Tuesday evening, it's designed for adults with access to a DSLR and tripod (a telescope is not required) and costs £96. **rmg.co.uk**

The Early Formation of Galaxies

Queen's Buildings, Cardiff University, 5 October, 7pm

Cardiff Astronomical Society hosts Dr Nicolas Peretto, from Cardiff University's Hub for Astrophysics Research and Technology, for a talk in which he outlines the best theories we currently have about how galaxies are formed. **cardiff-astronomical-society.co.uk**

A History of Women in Astronomy, Part 1

Online, 20 October, 7:30pm

In this online talk from the Astronomical Society of Edinburgh, astronomer, astrophotographer and occasional *Sky at Night* guest Mary McIntyre discusses some pioneering female stargazers, with Part 1 focusing on the women who came before the legendary Caroline Herschel. **astronomyedinburgh.org**

Surveying the Sky for Radio Galaxies

Church Green Road, Bletchley, 20 October, 8pm

The speaker for this year's Richard Lambert Memorial Lecture, in honour of Milton Keynes Astronomical Society's founder, is Professor Martin Hardcastle, an astrophysicist at the University of Hertfordshire. Non-members welcome. **mkas.org.uk**

Comets, Asteroids and Things that Fall from the Sky

Bredhurst Village Hall, Gillingham, 27 October, 8pm

The prospect of comet Halley's return in 1986 led to heightened interest in comets, asteroids and meteors. In this talk for Mid-Kent Astronomical Society, David Southward discusses the importance of these fragments from the formation of the Solar System. **midkentastro.org.uk**

Martin Mere Star Party

Martin Mere Wetland Centre, Burscough, Lancashire, 28 October, 7pm

With a partial lunar eclipse due, Liverpool Astronomical Society hosts an evening with displays, activities, talks and, of course, plenty of telescopes for hands-on observing. **liverpoolas.org/events**

PICK OF THE MONTH

▲ Will Gater's live show takes a trip through the Universe's most extraordinary wonders

Watch This Space

The Concorde Club, Southampton, 8 October, 7:30pm

Ever longed to unlock the secrets of the distant cosmic objects we see in the night sky? In this new touring show, astronomer, astrophotographer and former *BBC Sky at Night Magazine* news editor Will Gater, FRAS, who's been described as "one of the current generation of 'rock star' science popularisers", blends visuals, live demonstrations and inspiring storytelling to take the audience on a journey out into the Milky Way and beyond as he delves into the big questions: what's 'out there' and what is our place in the Universe? The show moves on to Pershore, Worcestershire next month, with more dates to be announced. Tickets £25. **willgater.com/watchthisspace**

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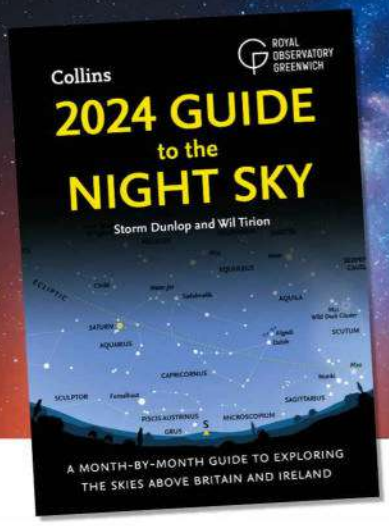
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FIELD OF VIEW

By the light of the silvery Moon

Jonathan Powell considers the natural world's connection to the Moon and stars

ALEX GREEN/FOLIO

Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he is currently astronomy columnist at the *South Wales Argus*

Watching a crescent Moon slowly drift westward in the fading light of an evening sky may not be all that scientific, but it does serve as a reminder that perhaps we aren't the only ones drawn to its movement across the heavens. Indeed, humankind is just one of many living things touched "By the Light of the Silvery Moon", as Doris Day sang in the 1953 film of the same name.

The umbilical-chord existence that tethers Earth to the Moon is an incredibly strong bond, as both worlds duet their way around the Milky Way – a bond that's absolutely crucial for so many species.

For the baby turtle after hatching amid the sand, the gaze of its freshly opened eyes focuses in on the moonlight reflected off the nearby sea, acting as a beacon to guide the turtle safely to the water's edge. Interestingly, to the ancient Scots, Norse, Polynesians and Native Americans, the shell of a turtle was of enormous interest.

The shell, when viewed from above, was seen to comprise 13 major inner segments and 28 outer segments around the shell's edge. These divisions were interpreted as 13 Moons and 28 days, the equivalent to 364 days plus one day of rest. No doubt you can buy a calendar with turtles on it today; but to them the turtle itself was a 13-month calendar, incorporating 13 Moon cycles a year, each made up of 27–29 days.

Turning to birds, the European nightjar's migratory pattern is synchronised with lunar cycles. Aside from the Moon, most songbirds like thrushes and warblers migrate at night, choosing a single star like Polaris for guidance, gauging the movement of the constellations relative to the star, thus calculating the direction they need to be travelling. At night, the air is cooler and calmer too, meaning that birds use less energy on their long migratory journeys, with the added bonus that travelling under the cover of darkness means less predators.

The moth, like other insects, engages in behaviour known as transverse orientation, navigating by flying at a constant angle relative to a light source, such as the Moon. However, if the moth were to fly past an outside light, the angle of light relative to the moth changes, confusing the insect's delicate navigation. That is why you see them bumping into lights again and again, as if trying to rectify the disorientation. Entomologists have found that moths are less attracted to artificial lights during the week of a full Moon than the week of a new Moon.

Plenty of other creatures, including frogs, seals, and dung beetles, use the Moon and stars for navigational purposes. Indeed, the humpback whale uses several natural aids to navigate, including not just the Moon and stars, but also the Earth's magnetic fields.

The link that exists between wildlife and the Moon is strong – but it is under threat. Light pollution is causing increasing disruption, to the point where migrating birds can be unable to navigate properly and baby turtles can be drawn in the direction of artificial lighting rather than following the Moon's light towards the safety of the water.

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BBC Sky at Night MAGAZINE

Astronomy Photographer of the Year

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BBC Sky at Night Magazine is proud to reveal the 2023 winners of the world's biggest astrophotography competition

Once again, astronomy photographers from around the world have battled it out to claim the prestigious title of Astronomy Photographer of the Year 2023. This year, entrants from 64 countries submitted over 4,000 incredible images. From these, the judges have selected the best in each of eight categories, as well as two special prizes for best newcomer and for processing data taken by professional observatories, as well as a special prize for entrants younger than 16 years old. You can see the spectacular winning photos for yourself at the National Maritime Museum in Greenwich, London from 16 September. For details, visit **www.rmg.co.uk/astrophoto**.

FREE 2024 CALENDAR

Don't miss the December issue of *BBC Sky at Night Magazine* for our free 2024 calendar featuring all the incredible top images from this year's Astronomy Photographer of the Year competition, as well as all the unmissable astronomical events to see in the night sky in the year ahead. It goes on sale from 16 November 2023.

MORE ONLINE

A gallery of these and more stunning images from the 2023 competition

Watch our Masterclass series on Deep-Sky Imaging to get expert advice on taking great astro images of your own. Tickets start from £15. **www.skyatnightmagazine.com/virtual-events**

OVERALL WINNER / Galaxies ▷

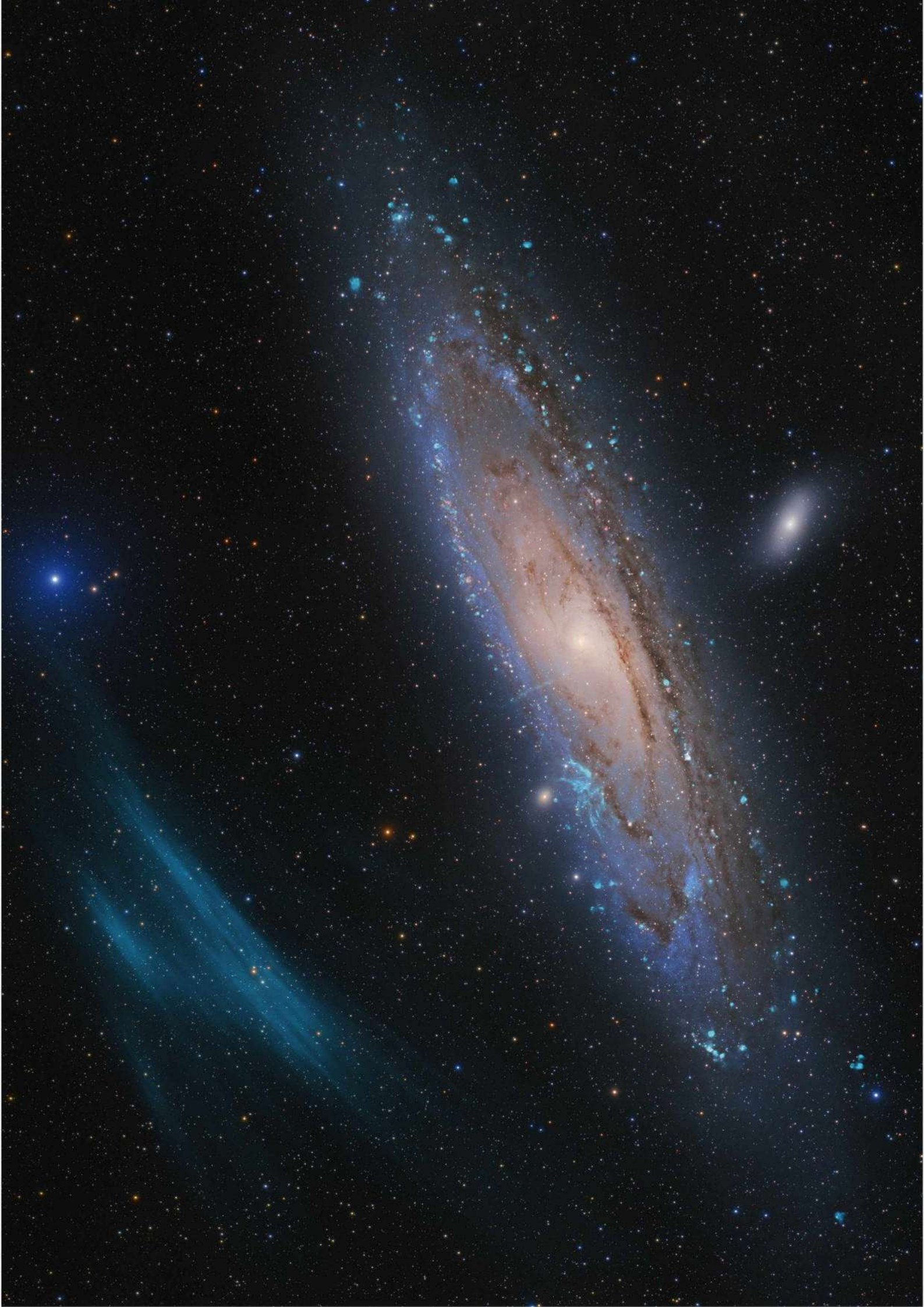
Andromeda, Unexpected

Marcel Drechsler, Xavier Strottner, Yann Sainty

Location: Near Nancy, France
Equipment: Takahashi FSQ-106EDX4 telescope, Sky-Watcher EQ6 Pro mount, ZWO ASI2600MM Pro camera, 382mm f/3.6, 111 hours

When an international team of astronomers joined forces to take this image, none of them were expecting to make a scientific discovery. And yet, their final image revealed a great arc of plasma next to the Andromeda Galaxy, which could be the largest such structure in the nearby Universe.

Judge's verdict: "What does a discovery image look like? It is mostly a blurry black and white image that depicts an almost invisible faint dot or a spectrum that is incomprehensible to us. However, that was not the case this time. This astrophoto is as spectacular as it is valuable. It not only presents Andromeda in a new way, but also raises the quality of astrophotography to a new level."
– László Francsics



△ Our Sun

A Sun Question

Eduardo Schaberger Poupeau

Location: Rafaela, Santa Fe, Argentina
Equipment: Sky-Watcher Evostar 150ED DX refractor, Daystar Quark Chromosphere filter, Baader ERF frontal filter, iOptron CEM70G mount, Player One Apollo-M Max camera, 840mm focal length, 120mm aperture, 2 panels of 115x 3.47 milliseconds

Judge's verdict: "This is such a clever image as, while we have seen the granulation and the surface of the Sun before, I've never seen a filament shaped like a question mark before. If you zoom into the surface of the Sun, the image has a paint-like quality – I feel like I can see the brush strokes." **– Sheila Kanani**

△ Our Moon

Mars-set

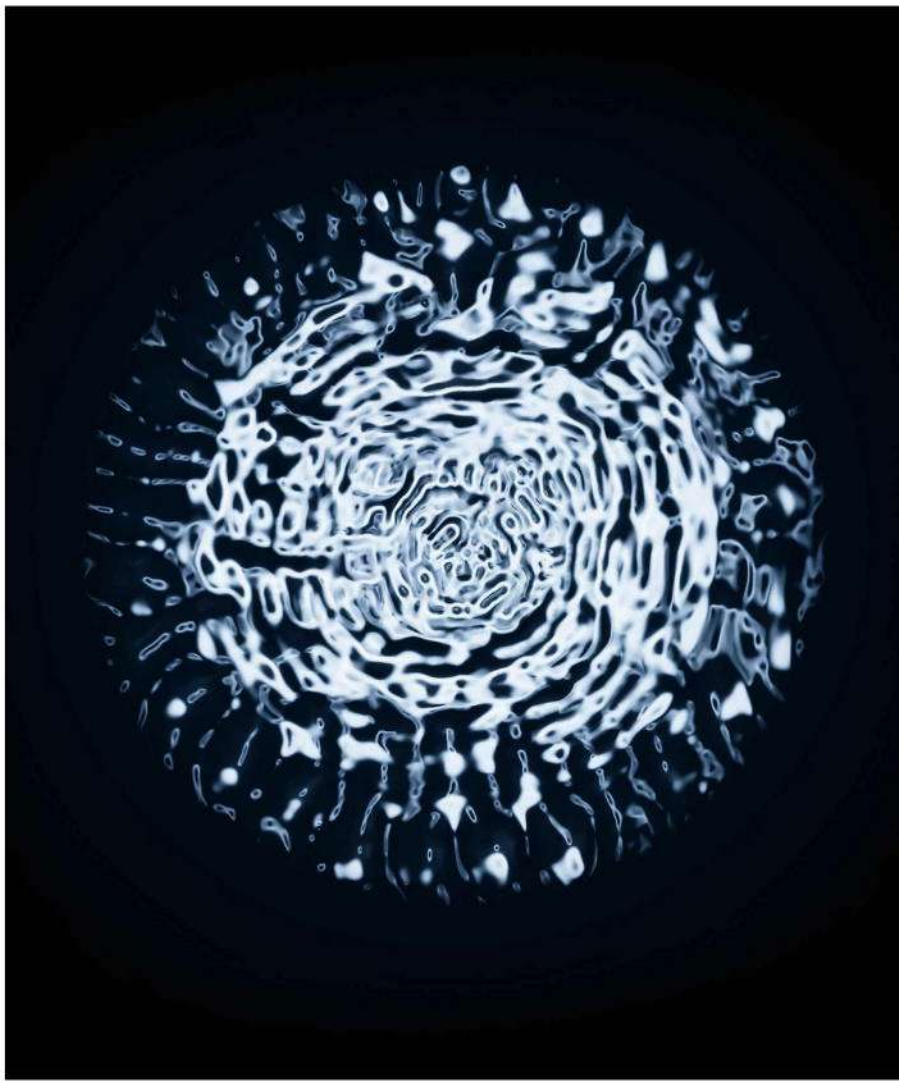
Ethan Chappel

Location: Cibolo, Texas, USA

Equipment: Celestron EdgeHD 14-inch telescope, iOptron CEM70 mount, Astro-Physics BARADV lens, ZWO ASI462MC camera, 7,120mm f/20, multiple 15-millisecond exposures

Judge's verdict: "The occultation of Mars by the Moon was one of the last and greatest celestial events of 2022. It was also one of the most challenging to image. To capture the level of detail on Mars that you see here takes a huge amount of skill and practice." **– Steve Marsh**

The Annie Maunder Prize for Digital Innovation ▷



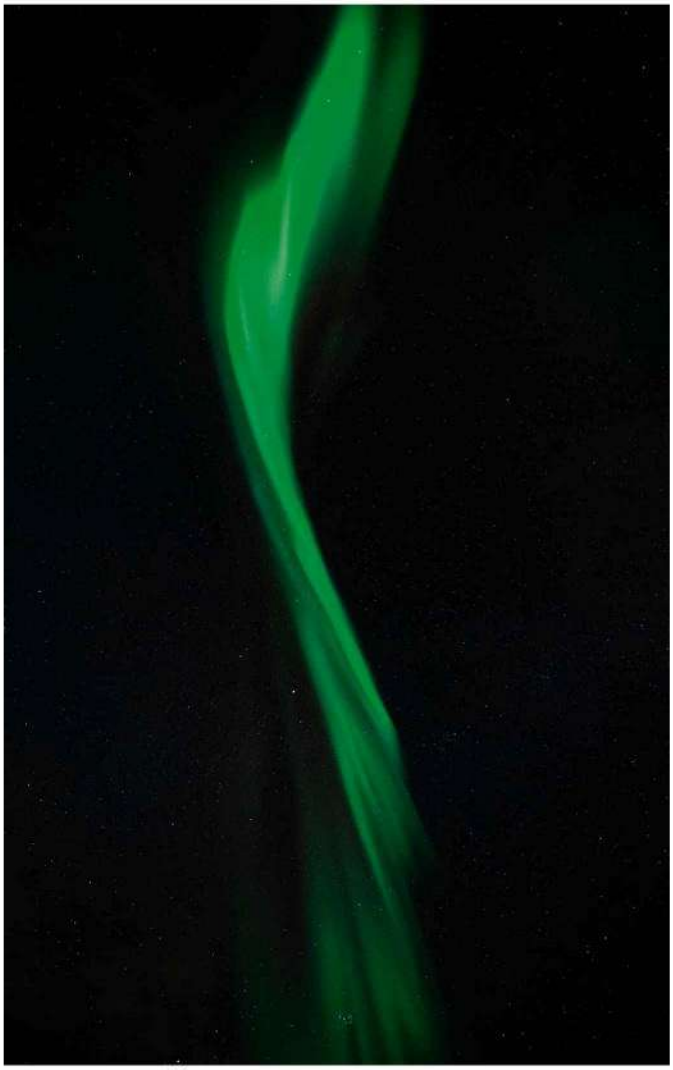
Black Echo

John White

Original data: NASA Chandra X-ray Observatory, May 2022

When NASA's Chandra X-ray Telescope captured the sound of the Perseus Galaxy's supermassive black hole, they had to shift the sound by 57 octaves to allow humans to hear it. White then took this sound and played it through a petri dish of water, capturing the dancing liquid to provide a visual representation of the otherwise invisible sound.

Judge's verdict: "Most of the information in the Universe is imperceptible to human senses. Interpreting and presenting that information is vital as well. Here, we are shown an interesting and playful visualisation of astronomical data that we could not 'see' by ourselves, nor 'hear'. Stark, beautiful, rather weird, and certainly innovative!" **– Ed Bloomer**



△ People and Space

Zeila

Vikas Chander

Location: Heintesbaai (Henties Bay), Erongo region, Namibia
Equipment: Nikon D850 camera, 135mm f/2.8, ISO 200, 30-minute exposure
Judge's verdict: "I really love how the star trails poking through the grey sky provide a stunning backdrop for this stranded ship. It's a hauntingly beautiful image that would be the perfect setting for a ghost story and is one of my favourites from this year's competition." **– Melissa Brobby**

▽ Planets, Comets and Asteroids

Suspended in a Sunbeam

Tom Williams

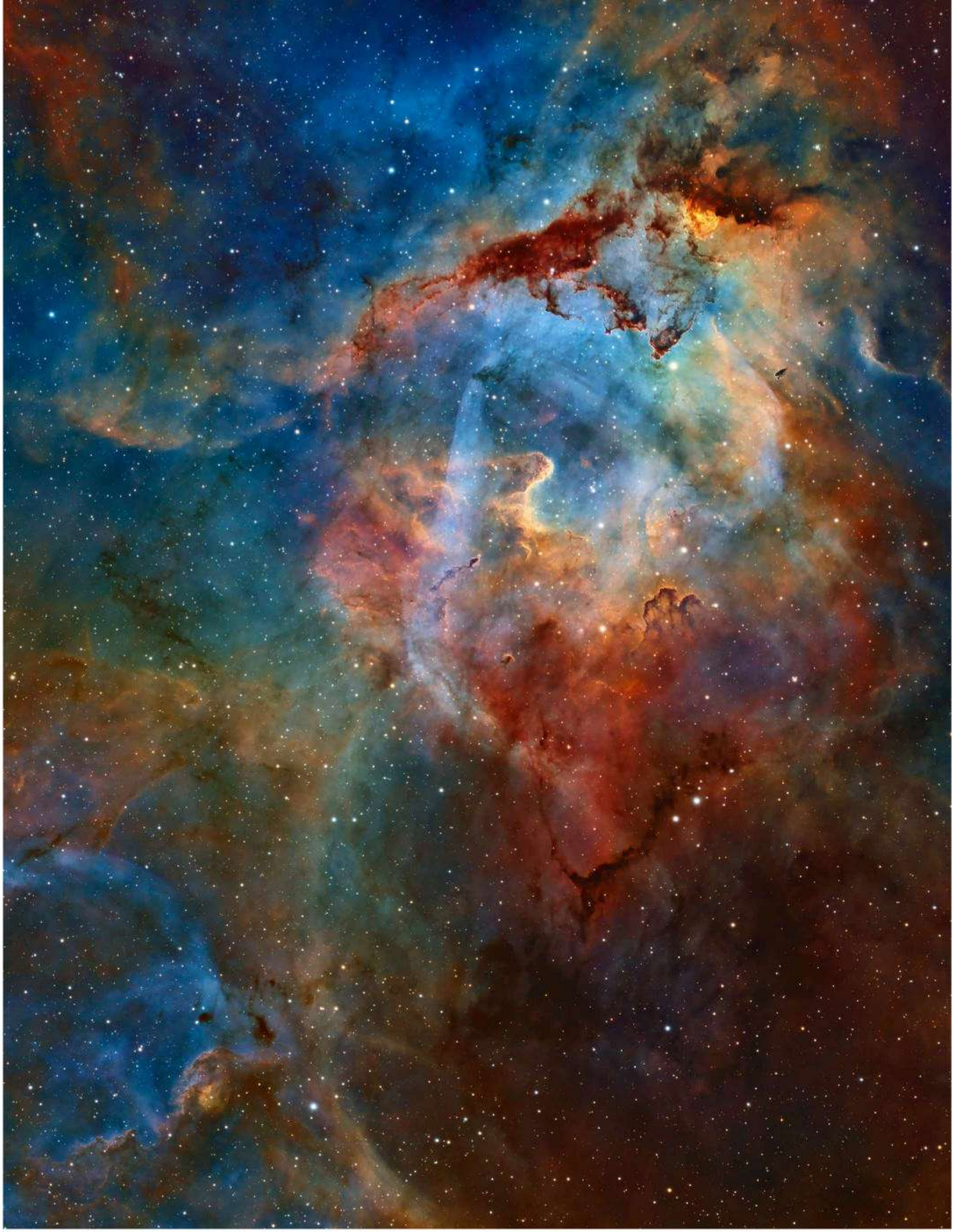
Location: Trowbridge, Wiltshire, UK
Equipment: Sky-Watcher 400P 16-inch Go-To Dobsonian, Baader Bessel (U)BVRI and ZWO IR850 filters, ZWO ASI462MM (Early-Bird) camera, 8,750mm f/21.5, 133.75-second exposure in IR/UV
Judge's verdict: "Venus can be easily found with the naked eye or photographed with a small telescope, as it's the planet with the largest angular diameter that can be seen from Earth. But not like this. Capturing these atmospheric details when it's so far from Earth is a remarkable achievement." **– László Francsics**

△ Aurorae

Brushstroke

Monika Deviat

Location: Utsjoki, Lapland, Finland
Equipment: Nikon D850 camera, 14mm f/2.8, ISO 3200, 4-second exposure
Judge's verdict: "We're accustomed to seeing aurorae with mountains, trees and human-made structures framing the dancing lights. This offers something different, showcasing the beauty of the aurora in isolation. The composition evokes the arts of brush-painting and calligraphy practiced in many cultures around the world." **– Katherine Gazzard**



△ The Sir Patrick Moore Prize for Best Newcomer

Sh2-132: Blinded by the Light

Aaron Wilhelm

Location: Santa Monica, California, USA
Equipment: William Optics Fluorostar 132mm telescope, Chroma 3nm/50mm SII/H-alpha/OIII filters, Astro-Physics Mach2GTO mount, ZWO ASI6200MM Pro camera, 910mm f/6.9, 66.5 hours total exposure

Judge's verdict: "The perseverance and stamina of astrophotographers is what makes us truly stand out in the photography field. This photographer has put in the hours and studied their craft to create a beautiful image of this field of nebulosity. With subtle but varying colours across the whole palette, the dark twisting lanes of dust are resolved in exquisite detail and the stars are perfectly round with no hint of trailing. It shows that, even at the early stages of astrophotography, there are no limits to what we can achieve." **– Steve Marsh**

◁ Stars and Nebulae

New Class of Galactic Nebulae around the Star YY Hya

Marcel Drechsler

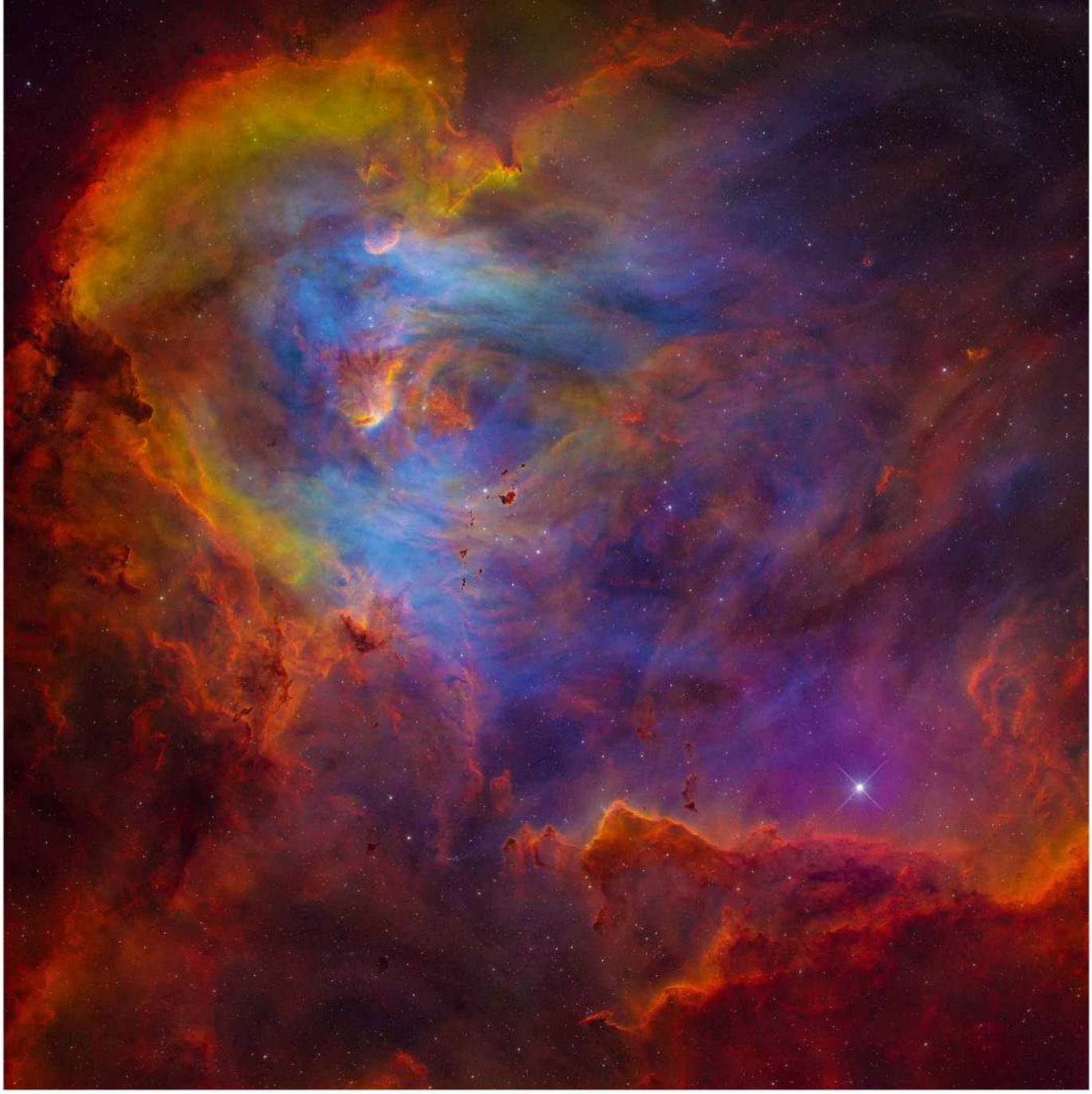
Location: Ovalle, Chile
Equipment: ASA Newtonian 500mm telescope, ASA DDM85 mount, FLI ProLine 16803 camera, 1,900mm f/3.8, 360 hours total exposure
Judge's verdict: "This is an absolutely breathtaking image of the YY Hya star and its interstellar environment. Remarkably, the nebula was discovered during a search for previously unknown galactic emission nebulae. After more than 360 hours of exposure time, the photographer revealed a gorgeous ultra-deep stellar remnant."
– Yuri Beletsky

▽ Skyscapes

Grand Cosmic Fireworks

Angel An

Location: Lake Puma Yumco, Tibet, China
Equipment: Sony ILCE-7SM3 camera, 135mm f/1.8, ISO 12,800, 4-second exposure
Judge's verdict: "This is not, as it might first appear, an enormous extraterrestrial, but the lower tendrils of a sprite (red lightning). This rarely-seen electrical discharge occurs high in the atmosphere. While the gradient of colours is beautiful, impressively the image also reveals the delicate structure of the plasma." **– Ed Bloomer**



△ Young Astronomy Photographer of the Year

The Running Chicken Nebula

Runwei Xu and Binyu Wang

Location: El Sauce Observatory, Río Hurtado, Chile
Equipment: ASA 20N f/3.8 Newtonian telescope, ASA DDM85 mount, FLI ProLine 16803 camera, 1,900mm f/3.8, 5.5 hours total exposure

Judge's verdict: "The photographers have managed to capture the vibrant colours of the nebula as well as the embedded star cluster. This cluster contains several hot, young stars whose intense radiation causes the surrounding nebula to glow. The interaction between the stellar winds from these stars and the denser pockets of material in the nebula leads to the creation of interesting features, such as Thackeray's globules, potential sites of future star formation." **– Yuri Beletsky**

The judges

Imad Ahmed: Director of the New Crescent Society

Yuri Beletsky: Astrophotographer and astronomer at Las Campanas Observatory

Ed Bloomer: Senior Astronomy Manager: Digital & Data at Royal Museums Greenwich

Melissa Brobby: Amateur astronomer, journalist and science communicator

László Francsics: Architect, Chairman of the Hungarian Astrophotographers' Association and overall winner of the Astronomy Photographer of the Year competition in 2019

Sheila Kanani MBE: Education, Outreach and Diversity Officer for the Royal Astronomical Society

Katherine Gazzard: Curator of Art (Post-1800) at Royal Museums Greenwich

Steve Marsh: Art Editor of *BBC Sky at Night Magazine*

Alan Sparrow: Chair of the UK Picture Editors' Guild

OBSERVING *off the beaten track*

Fancy a change from those familiar stargazing targets you've visited time and again? **Stuart Atkinson** is your guide to 10 dramatic alternative night-sky wonders to seek out

It's easy to go out on a rare clear night and set off on an unadventurous tour of familiar objects with your telescope. It's understandable – people want to make the most of any gaps in the clouds. But it could also be a wasted opportunity. With the whole sky to explore, when the clouds clear shouldn't you be looking for things you haven't seen before? After all, when you go on holiday you don't just go into the same shops you have at home – you go exploring the backstreets and alleys, looking for unusual sights and experiences.

Here, we're going to lure you off your beaten celestial track, swapping objects you've probably looked at again and again for 10 fresh alternatives. All of our recommendations are visible before midnight on cool nights this autumn.

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

Breathe new life into your astronomy adventures by swapping your usual targets for some exciting new sights

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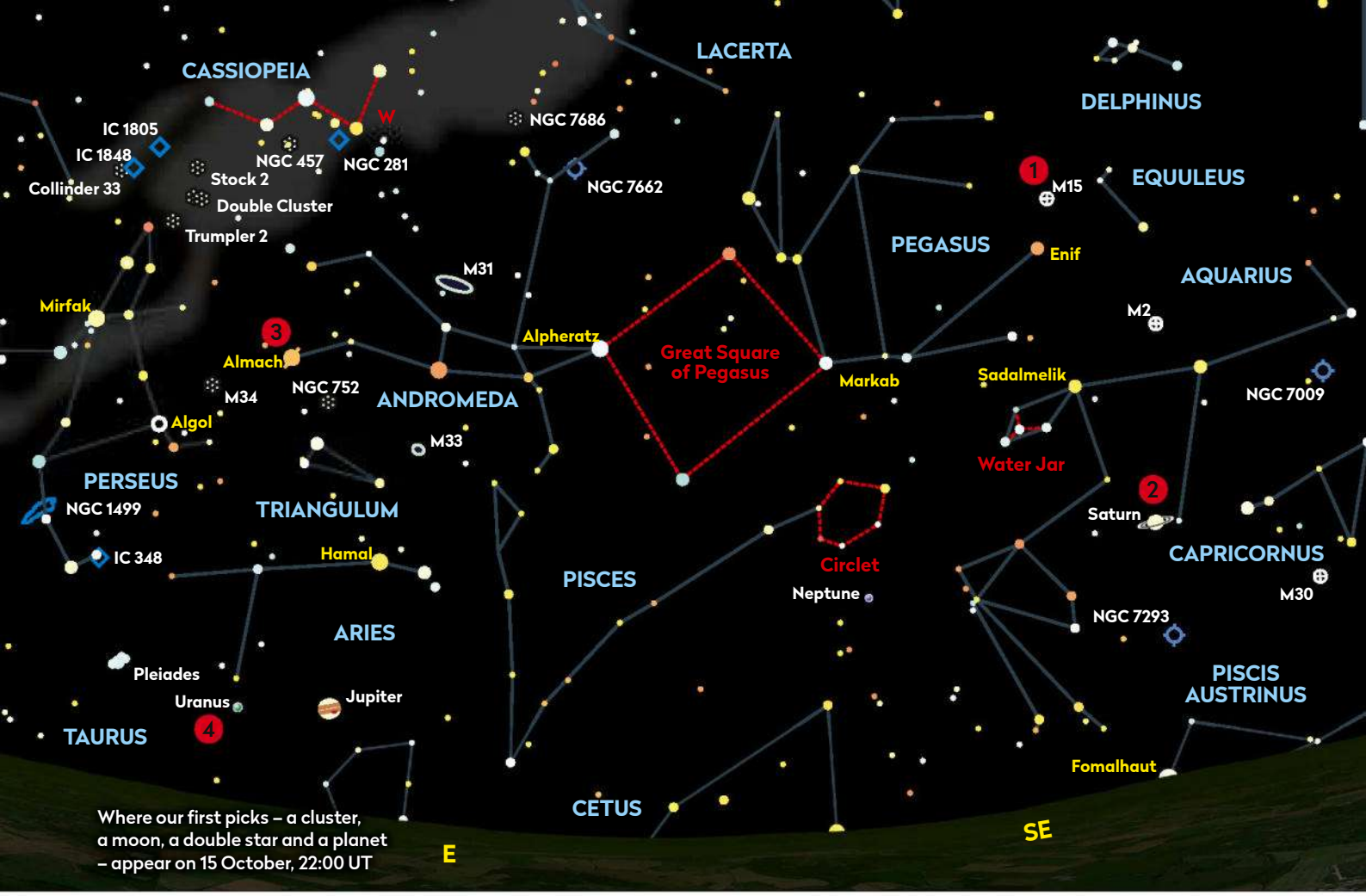


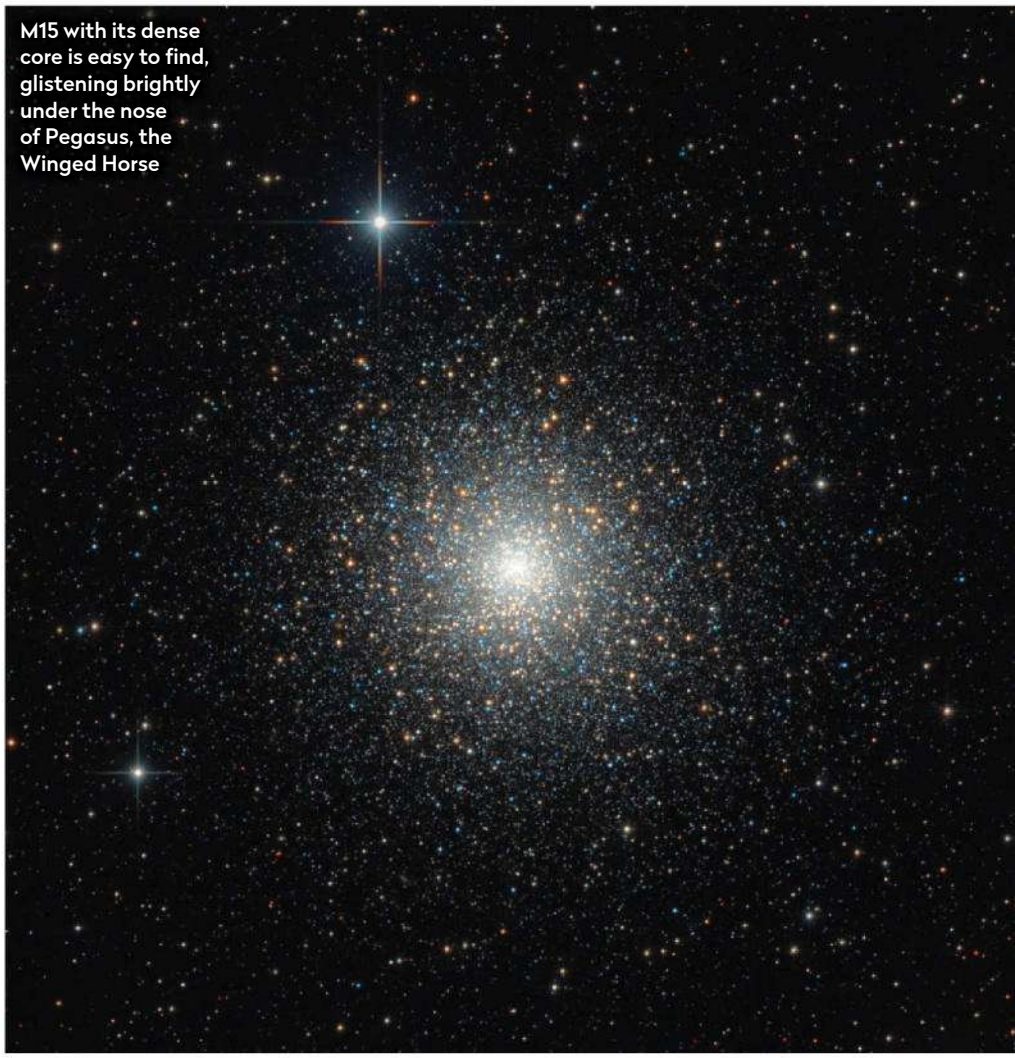
Where our first picks – a cluster, a moon, a double star and a planet – appear on 15 October, 22:00 UT

1. Globular cluster M15

INSTEAD OF: the Great Globular Cluster, M13

The most impressive globular cluster in the northern sky is generally accepted to be M13, the Great Globular Cluster in Hercules, and it is indeed a stunning telescopic treat, visible throughout this month in the western sky after sunset. But a short distance to its east, over on the opposite shore of the misty river of stars that is the Milky Way, lies another globular cluster that is well worth taking the time to find.

Close to one of the hooves of prancing Pegasus lies M15, a globular cluster with a magnitude of +6.2, which puts it just beyond the limits of naked-eye visibility. Binoculars show it easily as a large, fuzzy star, and 6-inch or larger telescopes reveal its bright, smoky core and a mist of fainter stars around it. With a diameter of 175 lightyears and a population of perhaps 350,000 stars, 13.2-billion-year-old M15 is one of the oldest globulars known. So by all means have a look at M13 before it sinks behind the trees, but then find M15. You won't be disappointed. ▶



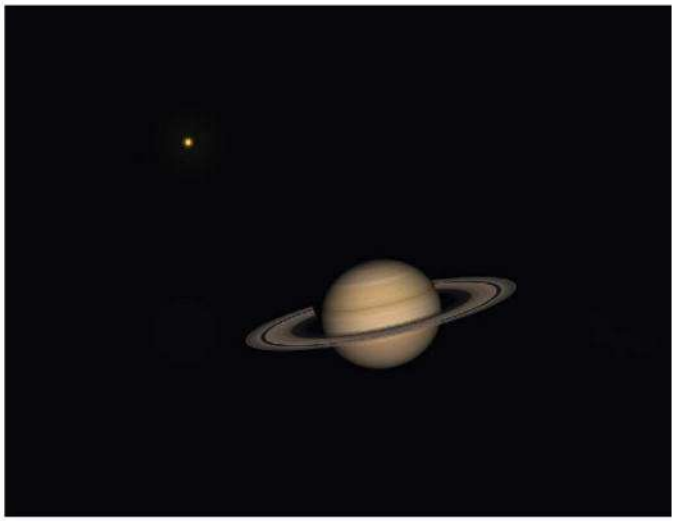
M15 with its dense core is easy to find, glistening brightly under the nose of Pegasus, the Winged Horse

2. Saturn's moon, Titan

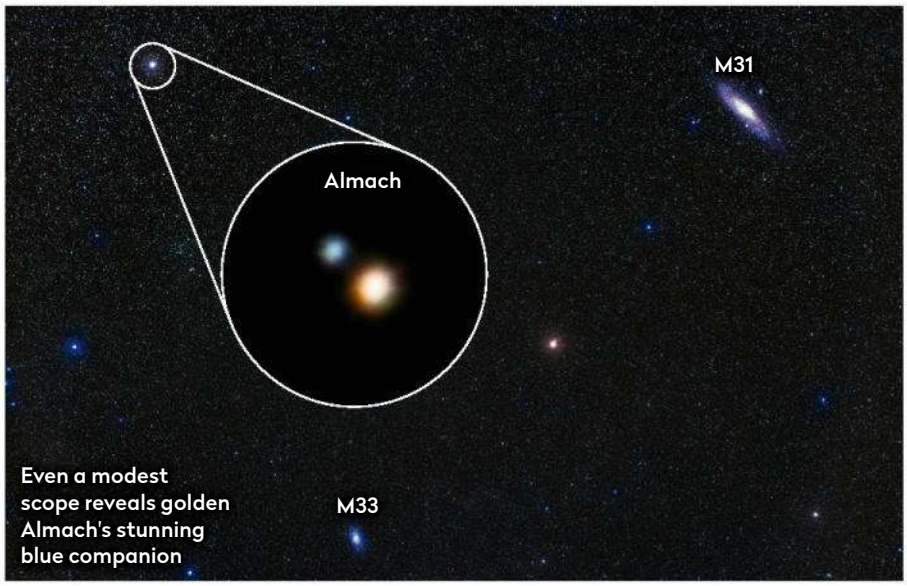
INSTEAD OF: the Galilean moons of Jupiter

Every amateur astronomer remembers their first view of the Galilean moons, Jupiter's four largest satellites, discovered by Galileo in 1610 using his celestial spyglass. It's very surprising that Galileo didn't discover Saturn's largest moon, Titan, too. After all, it is clearly visible in binoculars and small telescopes. But even today, in this age of computerised Go-To telescopes, a surprising number of people have never seen Titan.

If you're one of them, this is the time to change that. Discovered by Christiaan Huygens in 1655, Titan is the second-largest moon in the Solar System, with a diameter of 5,150km – bigger than the planet Mercury. You can see Titan for yourself this month by finding Saturn, low in the south as darkness falls. You'll need a planetarium app or program to identify which one of the many 'stars' around the planet is actually Titan though, because at magnitude +9.0 it will be fainter than many background stars. Having identified it, keep an eye on it over several nights to see how it moves slowly around the planet.



▲ How Saturn's orange moon Titan appears on 10 October, 23:00 UT. Titan can reach mag. +8.2 – well within the reach of binoculars



Even a modest scope reveals golden Almach's stunning blue companion

3. Almach, Gamma Andromedae

INSTEAD OF: Albireo, Beta Cygni

Double star observers are a special, select breed. While other amateur astronomers swoon and drool over the glowing gas and dust clouds of nebulae, the star-frothed arms of spiral galaxies or the rings, cloud bands or dusty surfaces of planets, double star aficionados delight in seeing pairs of stars with sequin-like contrasting colours. The most famous double star is probably gold and blue Albireo, in Cygnus, but close to the galaxy M31 is another double star that you really should get to know.

Almach, in Andromeda, looks like a single yellow-white star to the naked eye, but look at it through binoculars and you'll see it has a fainter, more sublime blue-hued companion close to it. Located 355 lightyears away from Earth, Almach is high in the sky and waiting for you as darkness falls on October nights, so don't just hopscotch past it as you head to M31, the Andromeda Galaxy!

Larger instruments bring out Uranus's amazing colour

4. Uranus

INSTEAD OF: Venus

Blazing in the dusky twilight like a lantern, Venus, the 'Evening Star', is often mistaken for the lights of an approaching aircraft. This month, it will be a brilliant 'Morning Star' visible before dawn. However, if you want more of an observing challenge, October is a great time to see Uranus.

Discovered by William Hershel in 1781, Uranus is an ice giant world that takes 84 years to orbit the Sun, more than 19 times further away from it than Earth. It is only just visible to the naked eye at magnitude +5.8, and that's if you have good eyesight and know exactly where to look. Binoculars make it easier to pick out as a green-hued point of light, but you'll need a telescope and high magnification to make out its disc. This month, it's found roughly half-way between the glittering Pleiades star cluster and the planet Jupiter.

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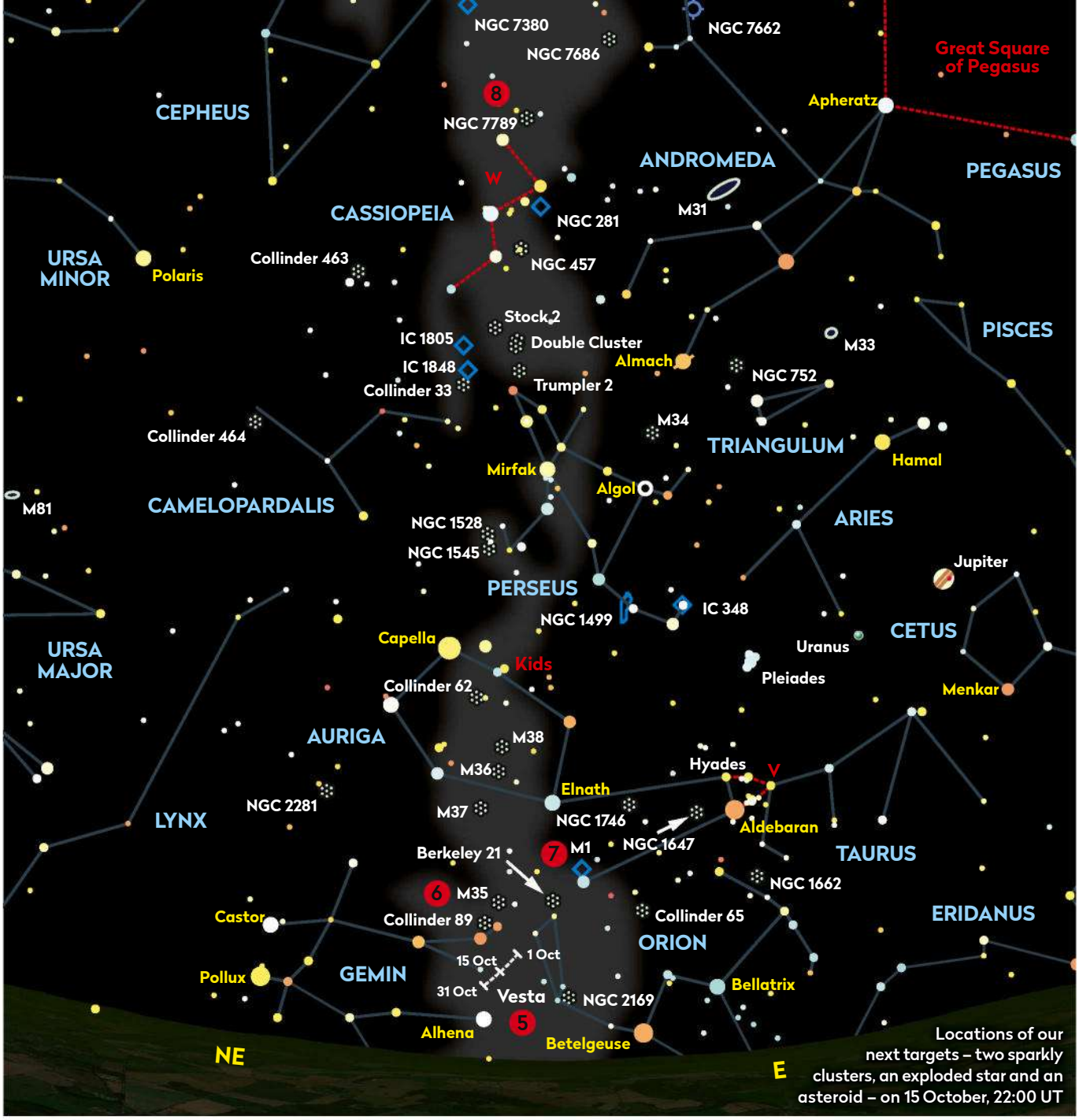
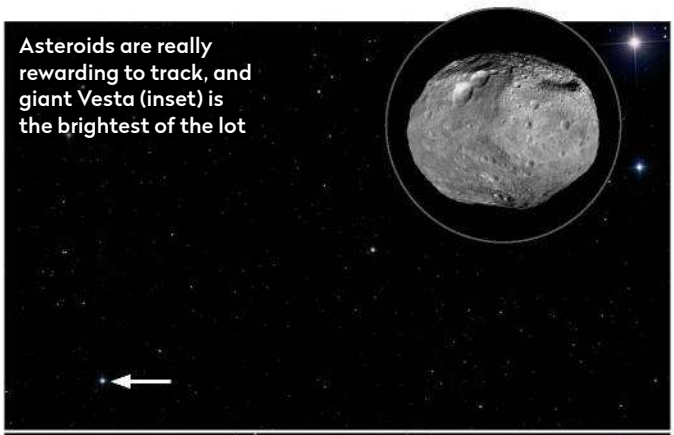
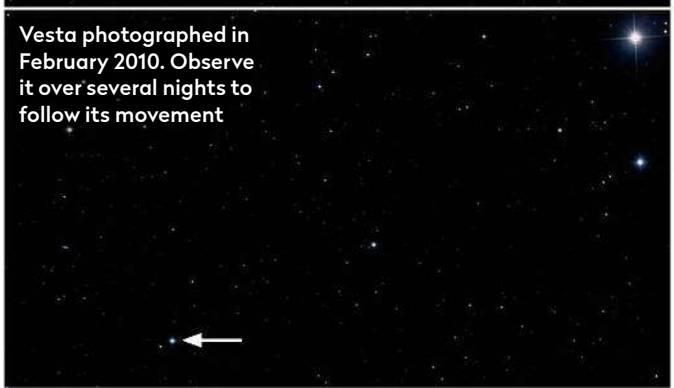


Locations of our next targets – two sparkly clusters, an exploded star and an asteroid – on 15 October, 22:00 UT



Asteroids are really rewarding to track, and giant Vesta (inset) is the brightest of the lot



Vesta photographed in February 2010. Observe it over several nights to follow its movement

5. An asteroid

INSTEAD OF: The Moon

For some astronomers, the Moon is an unwelcome visitor to the sky, a big, blindingly-bright ball that drowns out all the 'good stuff' and always returns at the wrong time, such as during a meteor shower's peak or when a comet is at its closest to Earth. For others, it's a fascinating world-next-door, with craters, mountains and canyons. Whichever camp you're in, for a change why not take a look at an asteroid?

This month, the second-largest known asteroid, Vesta, is well-placed in the sky, close to M35 in fact. Just shy of eighth magnitude, it's too faint to see with the naked eye, but you will see it as a star in binoculars. Unfortunately, even a large telescope won't show it as anything more than a point of light; although Vesta is a huge, tumbling ball of ancient rock 525km wide, it's always so far away that only the Hubble Space Telescope, or space probes – like Dawn, which visited it in 2011 – can make out its hummocky shape or see features on it. ▶

6. Star cluster M35

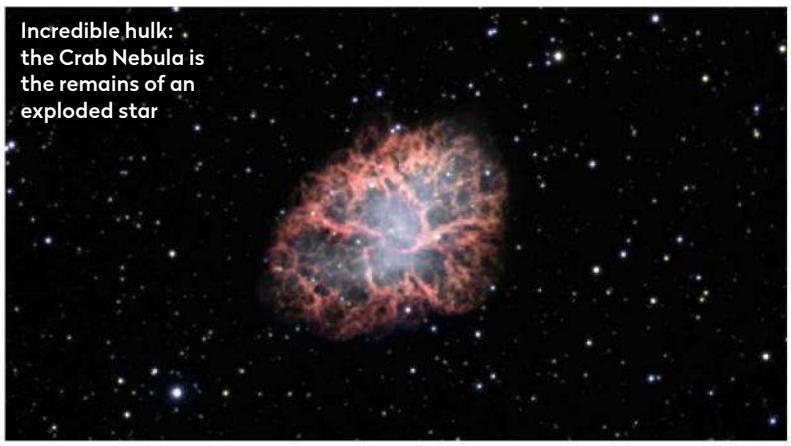
INSTEAD OF: the Pleiades

It may lack the Pleiades' instant pizazz, but M35 has subtle charms aplenty

Everyone loves the Pleiades – it's the first star cluster many people find in the sky, because it's so big and bright and obvious to the naked eye. Also known as the Seven Sisters because its seven brightest stars can be seen without any optical aids, through binoculars or a telescope this spill of gemstone stars never disappoints.

But there are other clusters around it that deserve your precious eyepiece time too. Nearby M35, in Gemini, is smaller and fainter than the Pleiades, but beautiful in its own right. Visible to the naked eye as a small, out-of-the-corner-of-your-eye smudge close to the feet of Gemini, this fifth-magnitude cluster is more easily seen in binoculars and is resolved as a misty speckle in telescopes.

Around 24 lightyears in diameter, the cluster contains at least 120 stars – perhaps as many as 500 – and lies 2,800 lightyears from Earth. On October evenings, M35 rises around 21:30 UT, and a couple of hours later it will be high enough to be seen at its best.



Incredible hulk: the Crab Nebula is the remains of an exploded star

7. M1, the Crab Nebula

INSTEAD OF: M42, the Orion Nebula

Ask a roomful of astronomers to name their favourite nebula and most will probably say, "The Orion Nebula". That's fair enough, as it's a truly spectacular sight in even a small telescope and very easy to find, glowing in the centre of Orion's Sword. But nearby lies one of the most important nebulae in the sky.

In 1054, a bright new star appeared in the constellation of Taurus, close to the tip of one of its fearsome horns. The 'new star' was actually a distant sun dying, blown apart in a supernova explosion. For the following 23 days the supernova shone at magnitude –6.0 and was clearly visible as a spark of light in the daytime sky. That star has long since faded, but in its place we can see a small misty patch: M1, the Crab Nebula. This 11-lightyear-wide cloud of gas and dust is completely destroyed by moonlight or light pollution, but under good conditions it can be seen through binoculars and small telescopes. Large telescopes show its vaguely crab-like shape, which gave it its name.

8. Star cluster Caroline's Rose

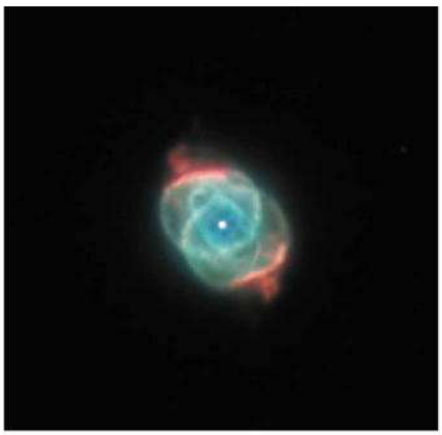
INSTEAD OF: the Double Cluster

Sweet Caroline: this open cluster has loops of blue and orange stars

The Double Cluster is a favourite autumn target for many observers. Located roughly half-way between the 'W' of Cassiopeia and the inverted Y of Perseus, this close pair of open star clusters looks like two piles of tiny diamonds spilled onto black velvet. But not too far away is a cluster that combines beauty with astronomical history.

Caroline's Rose is named after its discoverer, Caroline Herschel, sister of Uranus's discoverer, William Herschel. Located 7,600 lightyears away, its hundreds of stars span an area of around 60 lightyears. When viewed through a telescope at high magnification, the cluster's orange and blue stars, and the dark lanes between them really do resemble a rose with open petals. Caroline's Rose is estimated to be 1.6 billion years old; that's very old for an open cluster, but much younger than any globular cluster.

MARKUS BLAUENSTEINER/CCDGUIDE.COM X 2, FRANZ KLAUSER/MANFRED WASSHUBER/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM, DIETER BEER/PATRICK HOCHLEITNER/CCDGUIDE.COM, CHART BY PETE LAWRENCE



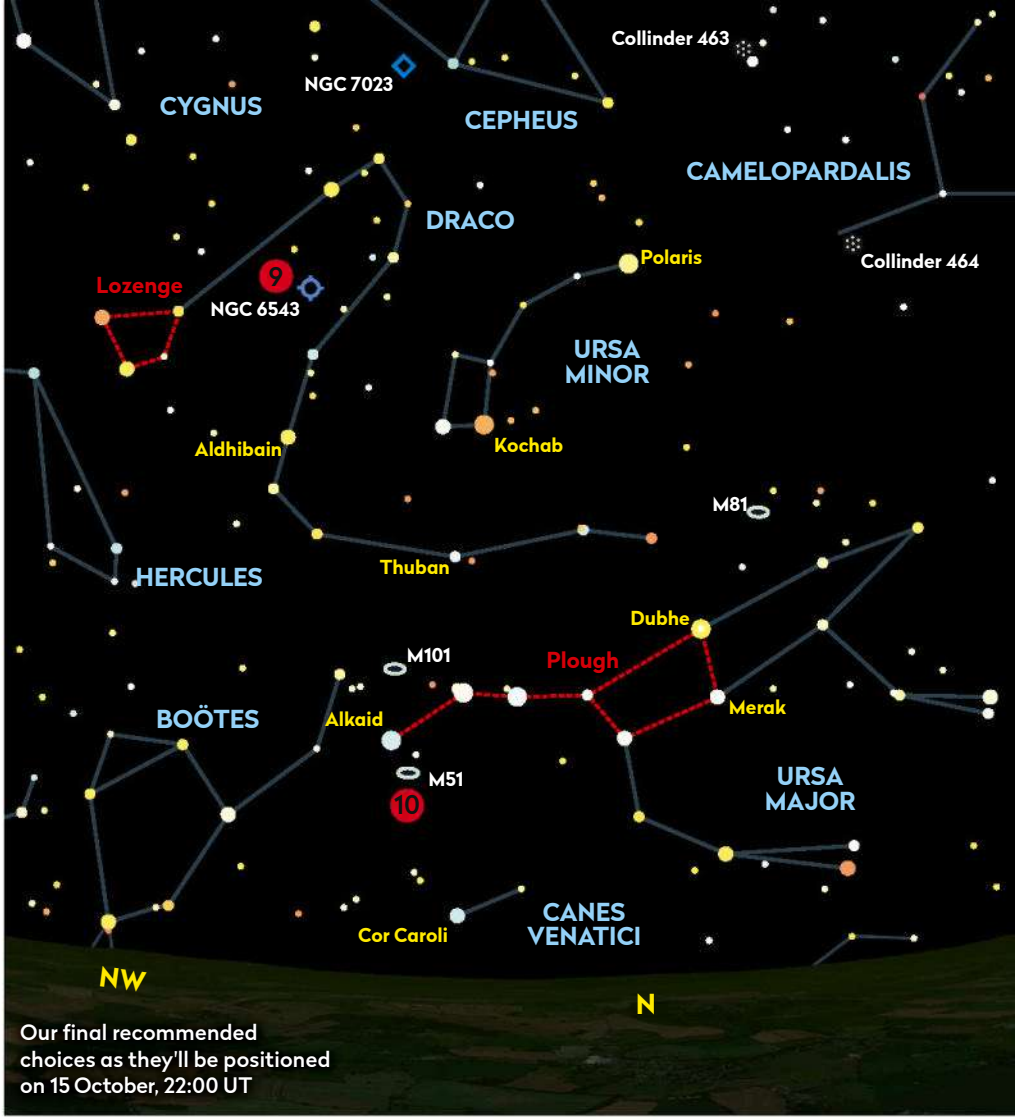
▲ Catch the eye: the ethereal Cat's Eye gets better and better as you up the power

9. The Cat's Eye Nebula

INSTEAD OF: the Ring Nebula, M57

Planetary nebulae are some of the most subtle and elegant deep-sky objects in the night sky. The most famous is probably M57, the Ring Nebula, which genuinely looks like a wispy smoke ring through a telescope. Although M57 is a summer favourite, it's still visible in October, over in the west after sunset, but the Cat's Eye Nebula, NGC 6543 in Draco, is a great alternative if you fancy a change.

Just over 3,000 lightyears away, and with a magnitude of just over +8.0, the nebula has a roughly lenticular shape in binoculars, and when seen through a telescope really does look like a cat's oval eye, with a bright centre surrounded by a fainter, oval haze. The nebula has been photographed in great detail by both the Hubble Space Telescope and the James Webb Space Telescope, and is a favourite target for amateurs with large telescopes and skies dark enough to use them to their full potential.



Our final recommended choices as they'll be positioned on 15 October, 22:00 UT

10. M51, the Whirlpool Galaxy

INSTEAD OF: M31, the Andromeda Galaxy

If you live in the Northern Hemisphere, M31 is *the* galaxy to gaze at on clear autumn nights. It's big (as wide as several full Moons), bright (easily visible to the naked eye) and already high in the sky as darkness falls. But there are many other galaxies available for your viewing pleasure too, and if you slowly sweep your binoculars around beneath the tip of the tail of the Great Bear, Ursa Major, you'll see a tiny smudge of pale grey, like an out-of-focus star. This is M51, aka the Whirlpool Galaxy, a vast spiral of billions of stars more than 28 million lightyears away, roughly equal in size to our own Milky Way.

This month is a fitting time to track down M51; although its beautiful spiral shape wasn't seen until 1845, when Lord Rosse turned the famous Leviathan telescope on it, this year will be the 250th anniversary of the galaxy's discovery, by Charles Messier on 13 October 1773. Small telescopes show M51 as a small oval-shaped blur, while a large telescope and high magnification will reveal its beautiful spiral shape.

Large, bright spiral M51 is a spectacular sight found near the end of the Plough's handle

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BBC Sky at Night MAGAZINE

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

OCTOBER 2023

A NIBBLE OUT OF THE MOON

Watch as the Moon's southern edge is covered by Earth's dark shadow

PETE LAWRENCE

A WANDER THROUGH THE 'W'

Take a tour of binocular and deep-sky targets in Cassiopeia

JUPITER MOON BINGO

Follow the moons and their shadow crossings

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Jupiter near opposition
- Favourable Orionids
- Binocular comet 103P/Hartley
- Tycho: get to know the lunar crater

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

OCTOBER HIGHLIGHTS

Your guide to the night sky this month

Sunday ▶ 1

Rising in the east-northeast around 20:00 BST (19:00 UT), the waning gibbous Moon and mag. –2.7 Jupiter appear 4° apart. At 02:30 BST (01:30 UT) on 2 October, they will be 2.6° apart.

Tuesday ▶ 3

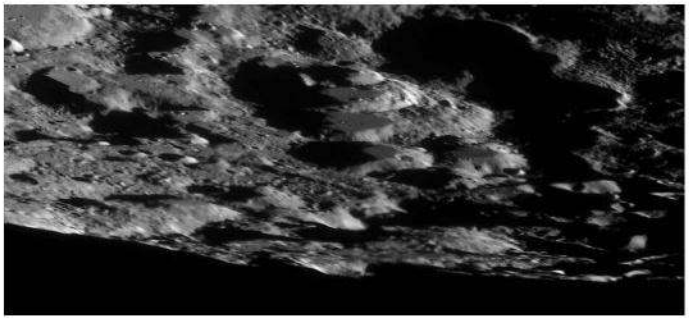
As dawn approaches, an 82%-lit waning gibbous Moon lies 1.7° south of the Pleiades.

Europa's shadow starts to transit Jupiter at 02:31 BST (01:31 UT).

Friday ▶ 6

Libration and phase are good for the south polar region of the Moon tonight.

Ganymede transits Jupiter 01:57–03:22 BST (00:57–02:22 UT). Io and its shadow are also in transit towards the end of this event.



Sunday 8

The Draconid meteor shower reaches its peak tonight and into tomorrow morning. Best chances are when the radiant is higher, as the sky darkens this evening around 20:30 BST (19:30 UT).

Monday ▶ 9

As the Moon slips out of the way, the night sky is left nice and dark for trying our Deep-Sky Tour on page 56. This month we're looking at objects in the western half of Cassiopeia.

Tuesday 10

This morning's 18%-lit Moon sits 7.4° north of mag. –4.4 Venus. Mag. +1.3 Regulus appears 2.3° north of Venus.

The Southern Taurid meteor shower reaches its peak.

PETE LAWRENCE X 5, BERNHARD HUBL/CCDGUIDE.COM

◀ Saturday 21

The peak of the Orionid meteor shower is expected at midnight tonight.

Phase and libration are good for the Moon's north polar region.

Sunday 22

Our October Moonwatch target is Tycho, which is best seen this month on 7–8 October, then tonight and tomorrow night 22–23 October, and near the full Moon on 28 October.

Saturday 28

A partial lunar eclipse occurs. The main (umbral) part of the eclipse occurs between 20:35 BST (19:35 UT) and 21:52 BST (20:52 UT). The full Moon closes in on Jupiter into tomorrow morning.

Sunday 29

British Summer Time ends at 02:00 BST, when the clocks go back to 01:00 UT.

The Moon occults mag. +4.3 Botein (Delta (δ) Arietis) from 23:10 UT tonight.

Thursday 5

Ganymede's shadow transits Jupiter near the planet's southern pole. The event starts at 22:46 BST (21:46 UT) and concludes at 00:52 BST on 6 October (23:52 UT on 5 October).

Saturday 7

The clair-obscur effect known as the Cutlass is visible this morning, formed by the Straight Wall, Rupes Recta, and the curving Stag Mountains.

Wednesday 11

As the bright Moon moves out of the way, this is a good time to look for binocular comet 103P/Hartley 2, currently moving through Gemini and expected to be around mag. +8.3. See page 53 for details.

Friday 13

Ganymede's shadow transits Jupiter's south polar regions 02:47–04:52 BST (01:47–03:52 UT). Io's shadow transits from 04:43 BST (03:43 UT), making a double shadow transit 04:43–04:52 BST (03:43–03:52 UT). The moons transit from 05:18 BST (04:18 UT).

Friday 20

A double Jovian shadow and moon transit occurs as dawn breaks. At 06:38 BST (05:38 UT), Io's shadow transit begins. Ganymede's is at 06:48 BST (05:48 UT). Io transits at 07:02 BST (06:02 UT) and Ganymede at 08:32 BST (07:32 UT) after sunrise.

Tuesday ▶ 24

Venus reaches greatest western elongation. Separated from the Sun by 46.4°, the brilliant naked-eye planet is visible in the morning sky over towards the east at 04:30 BST (03:30 UT).

Monday 30

Io and its shadow transit very close to one another this evening, the event starting at 20:31 UT.

Family stargazing

There's a partial eclipse of the Moon visible during the early evening of 28 October. This won't be a dramatic event as just a small portion of the Moon's disc will be covered by Earth's shadow. A great way to experience this event is to suggest making a drawing of the Moon, say at 20:00 BST (19:00 UT), then at 21:14 BST (20:14 UT), which is the point of greatest eclipse. Once this has been done, the two drawings can be compared to show how the eclipse changed the appearance of the Moon. The eclipse occurs between 20:35 and 21:52 BST (19:35–20:52 UT). **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

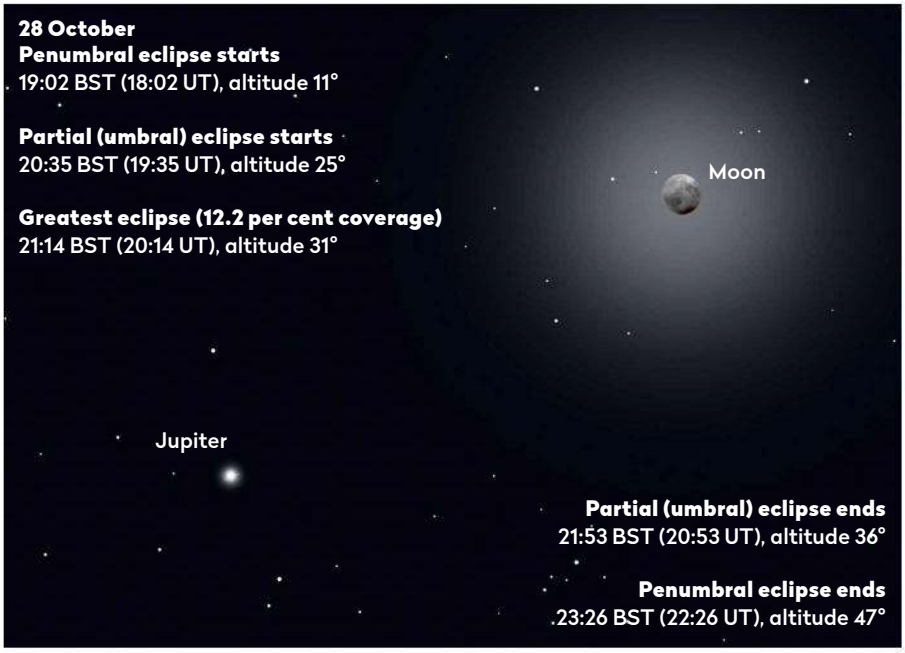
THE BIG THREE

The top sights to observe or image this month

DON'T MISS

Partial lunar eclipse

BEST TIME TO SEE: 28 October, from 19:02 BST (18:02 UT) until 23:26 BST (22:26 UT)


28 October
Penumbral eclipse starts
19:02 BST (18:02 UT), altitude 11°
Partial (umbral) eclipse starts
20:35 BST (19:35 UT), altitude 25°
Greatest eclipse (12.2 per cent coverage)
21:14 BST (20:14 UT), altitude 31°
Moon
Jupiter
Partial (umbral) eclipse ends
21:53 BST (20:53 UT), altitude 36°
Penumbral eclipse ends
23:26 BST (22:26 UT), altitude 47°

▲ The partial lunar eclipse on 28 October is small, but well-positioned for UK viewing

The Moon passes into Earth's shadow on 28 October, creating a lunar eclipse. This will be an interesting event because the Moon will graze the northern edge of the darkest portion of the shadow. This results in a small 'bite' appearing to be taken out of the Moon's southern edge.

From Earth, the Sun has an apparent size around half-a-degree. In other words, it's an extended rather than a point-source of light. The consequence of this is that from the Moon's orbital distance, Earth's shadow has two components: a weak outer part known as the penumbral shadow and a dark inner part called the umbral shadow.

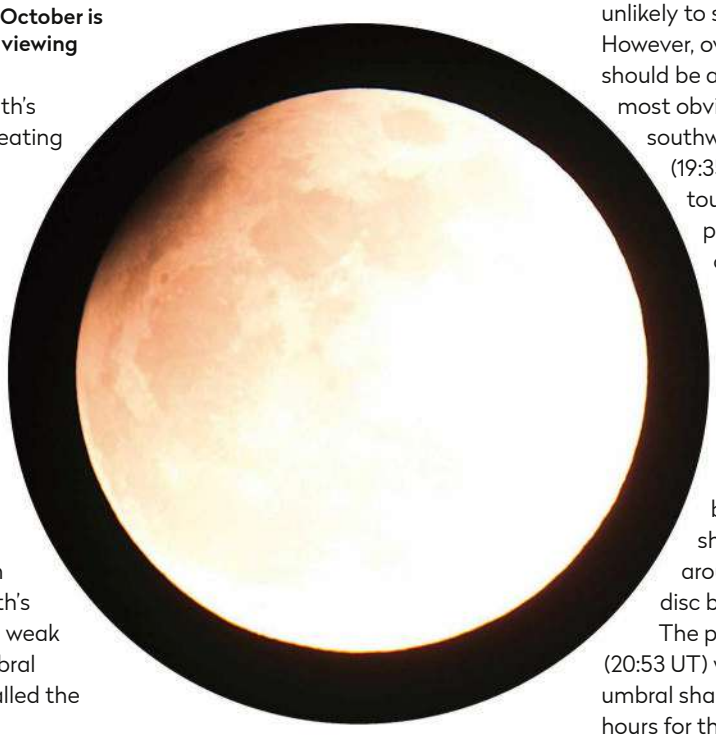
A spacecraft within the outer part of the penumbra would see a tiny fraction of the Sun's disc clipped by Earth. If the craft moved further inside the penumbral shadow towards the umbral shadow, the amount of clipping – essentially a partial eclipse of the Sun – would increase. Just outside of the umbral shadow, all but a tiny amount of the Sun's light would be hidden from view. Pop inside the umbra and all of the Sun's light would be hidden.

In the early evening sky on 28 October, although you obviously can't see it, the penumbral shadow will span an apparent diameter around 4.7 times the apparent diameter of the Moon. The umbral shadow's apparent diameter will be around 2.7 times larger than the apparent diameter of the Moon, both shadows being arranged concentrically like a bull's-eye target.

At 19:02 BST (18:02 UT), the Moon enters the penumbral shadow. The outer part of this shadow is so weak that you're unlikely to see anything at this time. However, over the next 1.5 hours you should be able to see a subtle darkening, most obvious near the Moon's southwest limb. Then at 20:35 BST (19:35 UT), the Moon's limb will be touching the umbral shadow, the point in time marking the start of the partial eclipse.

As mentioned, this is a small partial eclipse, just a glancing blow of the umbral shadow. Maximum eclipse occurs at 21:14 BST (20:14 UT), when around 12 per cent of the Moon's diameter will be covered by the umbral shadow; this translates as around 6 per cent of the Moon's disc being eclipsed.

The partial eclipse ends at 21:53 BST (20:53 UT) when the Moon slips out of the umbral shadow. It then takes around 1.5 hours for the Moon to slowly leave the subtlety of the weak penumbral shadow and by 23:26 BST (22:26 UT), the entire eclipse will be over.



▲ A small partial eclipse from 2013. Turn to page 55 to find details of how to bring out the colour of the umbral shadow

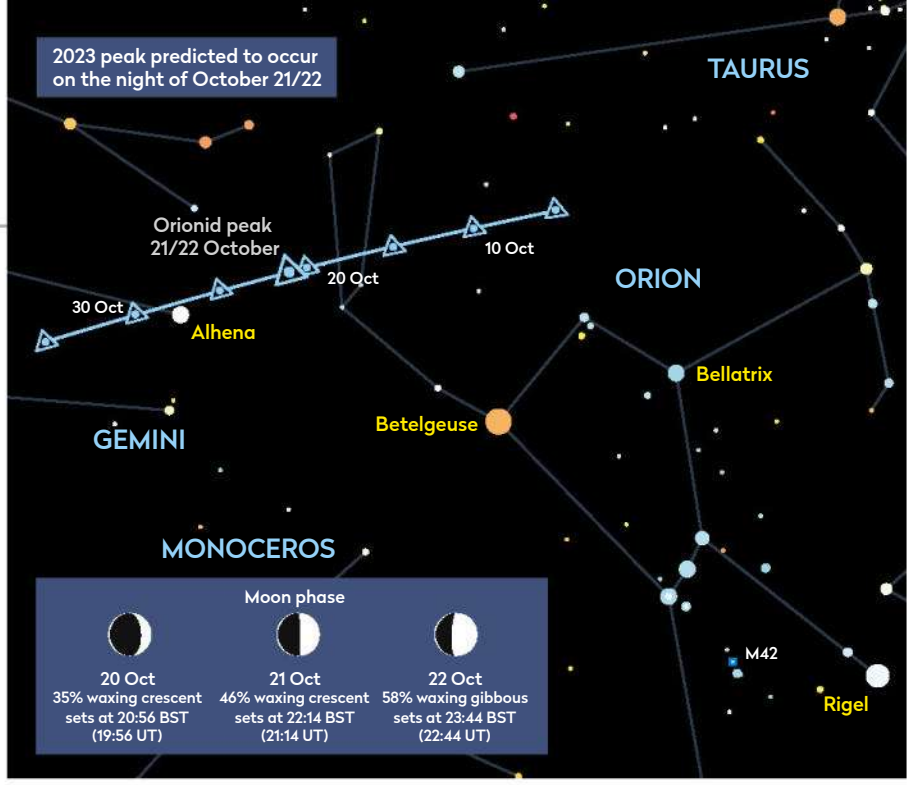
ALL PICTURES: PETE LAWRENCE

Orionids 2023

BEST TIME TO SEE: From 2 October to 7 November, peak activity 21/22 October

Although not the richest of the year's meteor showers, the Orionid shower is a firm favourite when the Moon is out of the way. This is the second of two meteor showers associated with Earth's crossing of the orbit of comet 1P/Halley, the first being the Eta Aquariids in early May, which are difficult to see from the UK due to their low southern aspect.

At their peak, the Orionids have a ZHR (Zenithal Hourly Rate) of around 20 meteors per hour. This year, the peak occurs on the night of 21/22 October, with the radiant above the eastern horizon from around 23:00 BST (22:00 UT). The Moon will be almost at first quarter, but luckily it also sets just before 23:00 BST (22:00 UT), leaving the whole night good and dark for Orionid hunting. The period to watch is from 23:00 BST (22:00 UT) on 21 October to 06:00 BST (05:00 UT) on 22 October – a total of 7 hours.



▲ **Early Moon interference gives way to dark skies for this year's Orionids**

The ZHR isn't the number of meteors you should expect to see, but rather what the shower is capable of given perfect conditions and with the shower radiant (the point from which the meteors appear to emanate) directly overhead. For UK viewers, the visual hourly rate will normally always be lower than the stated ZHR.

From the centre of the UK, the Orionids radiant approaches an altitude of around 50°, due south, just before the onset of dawn. Its location on the peak night is near the 'club' held aloft by Orion, northeast of Betelgeuse (Alpha (α) Orionis) and just to the west of Alhena (Gamma (γ) Geminorum).

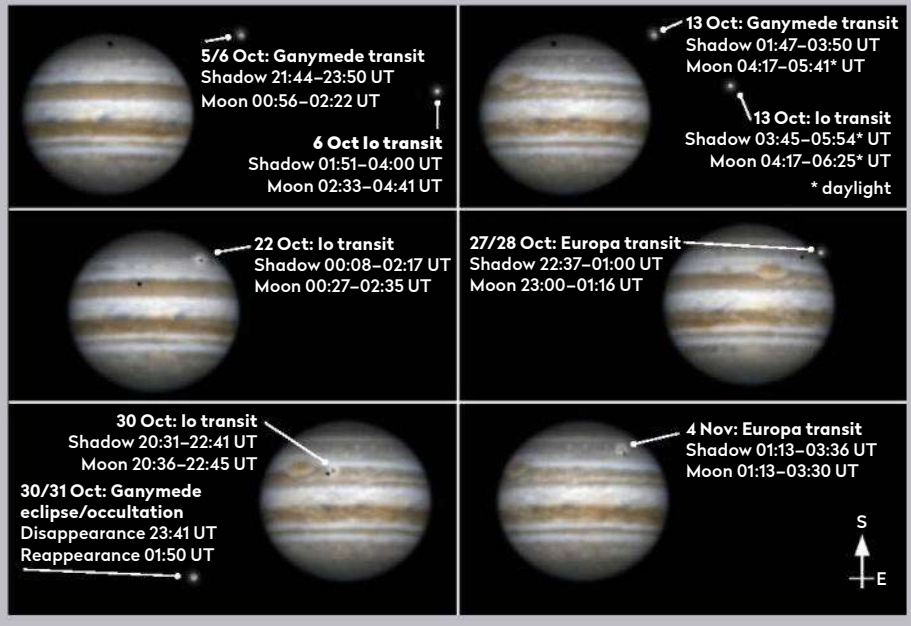
Jupiter moon events

BEST TIME TO SEE: As shown

Jupiter is approaching opposition, a time when it will be opposite the Sun in the sky. This occurs on 3 November. Opposition is the time when a planet appears largest and brightest to us viewing from Earth. Although you'll only be able to appreciate its size through the eyepiece of a telescope, Jupiter has an apparent diameter of 49.5 arcseconds on 3 November.

At opposition an interesting thing happens to the Galilean moons when they transit the planet. At this time their shadows appear to fall directly in line with the moons. The alignment would be perfect if the declination of the Sun from Jupiter were 0° and the Sun–Earth–Jupiter alignment a perfect straight line.

In practice the declination won't be 0°, but a little off at 3.1°. Catching a moon passing at the exact point of opposition



▲ **Follow these interesting Jovian moon events in the run-up to and after opposition**

is down to luck and an offset of just a few hours either side is enough to show a misalignment.

However, it is interesting to see how a moon's shadow precedes the moon that's casting it before opposition and follows it after opposition. In our graphic we've shown some interesting events to observe in the run-up to 3 November. We've included several so that if the weather is poor, you will hopefully stand a chance of seeing some of them.

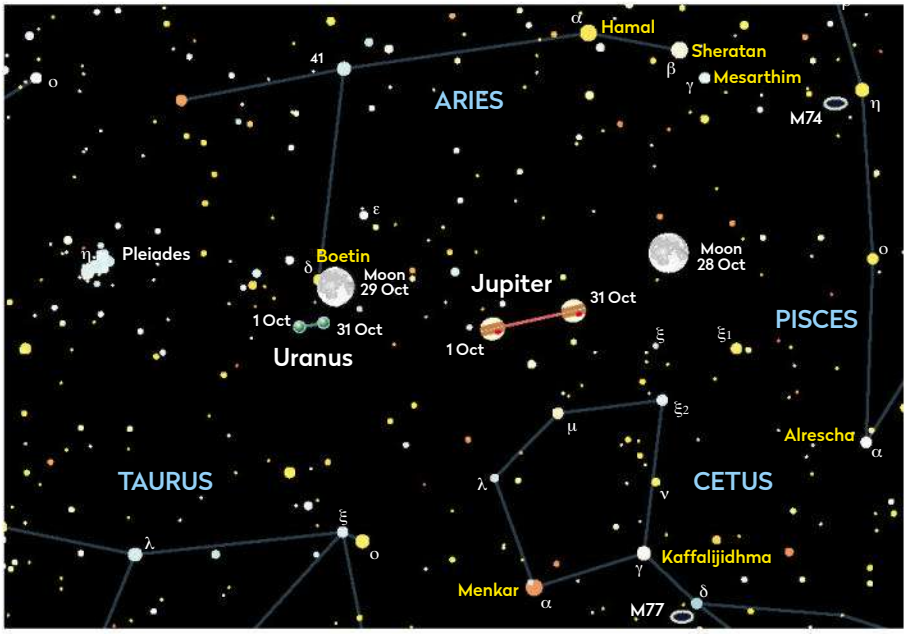
THE PLANETS

Our celestial neighbourhood in October

PICK OF THE MONTH

Jupiter

Best time to see: 1 October, 00:15 BST (30 September, 23:15 UT)
Altitude: 51°
Location: Aries
Direction: South
Features: Complex atmosphere, Galilean moons
Recommended equipment: 75mm or larger telescope



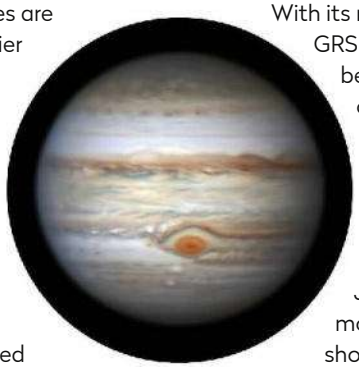
▲ **Jupiter is in a prime position, well above turbulence and very bright all month**

Jupiter reaches opposition on 3 November, and throughout October is well-placed for observing. From the UK, it's able to reach its highest position, around 51° up when due south, under truly dark skies. It's also very bright, shining at mag. –2.8. Consequently, it's a great time to observe and image this amazing world.

Through a small telescope, Jupiter's disc is obvious and appears squashed. Being a gas planet and rotating rapidly in under 10 hours, Jupiter's equatorial regions bulge and give the planet its oblate appearance.

If you give your eyes time to adjust to the view, the first detail you'll see on the planet's disc will be the two dark belts that run either side of and parallel to the equator. These are the north equatorial and south equatorial belts (NEB and SEB). Other belts and zones are also visible, becoming easier with greater aperture and steady skies.

Jupiter's atmosphere can appear complex and it's not always that easy to see the demarcation between the smaller belts and zones. The famous Great Red Spot (GRS) is embedded within the SEB in a scalloped region known as the Great Red Spot Hollow. Its visibility depends on when you observe the planet. With its rapid rotation period, the GRS may be visible or may be around the other side of the planet. Freeware applications such as WinJupos can tell you when it will be visible.



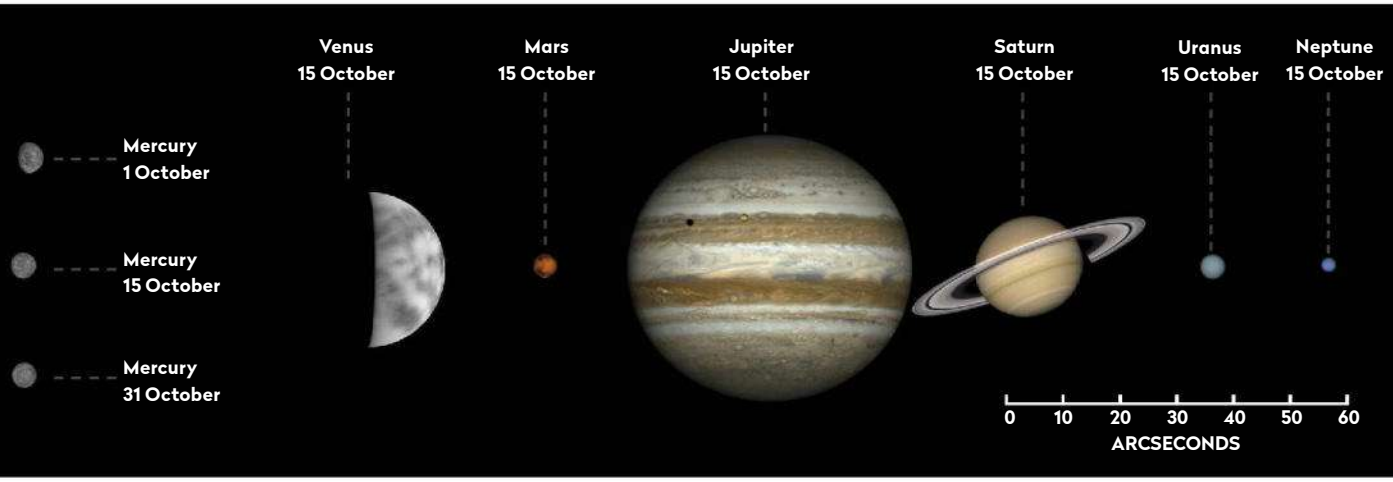
▲ **Jupiter imaged in August 2022, showing its famous Great Red Spot**

In addition to the rich, detailed atmosphere, Jupiter's four largest moons put on a regular show as they appear to interact with the planet. Turn to page 47 for the events to look out for this month.

PETE LAWRENCE X 2

The planets in October

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Mercury

Best time to see: 1 October, 40 minutes before sunrise
Altitude: 7° (low)
Location: Virgo
Direction: East

Mercury is a mag. –1.0 morning planet on 1 October, rising 90 minutes before sunrise. As October progresses, it moves closer to the Sun, brightening as it goes. On 7 October it's at mag. –1.1, rising one hour before the Sun. The Sun's glare engulfs the planet rapidly after this date. Superior conjunction occurs on 20 October, after which Mercury returns to the evening sky, when it'll be poorly positioned after sunset, setting with the Sun.

Venus

Best time to see: 24 October, from 06:00 BST (05:00 UT)
Altitude: 22°
Location: Leo
Direction: East-southeast

Venus is a bright morning planet. Shining at mag. –4.4, it reaches greatest western elongation on 24 October, separated from the Sun by 46.4°. On 10 October, it's joined by a 17%-lit waning crescent Moon and lies 2.3° from Regulus (Alpha (α) Leonis). At the start of the month, it rises 4 hours before sunrise and is visible against astronomically dark skies for around 2 hours. This figure increases towards the end of October, Venus rising 4.5 hours before the Sun and visible in true darkness for 2.5 hours.

Through the eyepiece on 1 October, Venus appears 36%-lit and 31 arcseconds across. On 31 October its phase increases to 54%-lit, its apparent diameter now 22 arcseconds. It's 50%-lit phase (dichotomy) should occur at greatest western elongation, but will be a few days late due to the phase anomaly.

Mars

Not visible this month

Saturn

Best time to see: 1 October, 22:50 BST (21:50 UT)
Altitude: 24°
Location: Aquarius
Direction: South

Saturn is well-placed in the evening sky, appearing at 24° altitude from the centre of the UK when due south. It appears like a mag. +0.5 off-white, yellowish star at the start of October, dimming to mag. +0.7 by the end of the month. A bright, waxing gibbous Moon appears near Saturn on the evenings of 23 and 24 October.

Uranus

Best time to see: 31 October, 02:50 UT
Altitude: 55°
Location: Aries
Direction: South

Uranus now reaches its best position, due south, under astronomically dark skies. At mag. +5.7, it will reach opposition next month, but being such a distant world, this doesn't change its appearance a great deal. By the end of October, the planet brightens to mag. +5.6 and presents a disc nearly 4 arcseconds across. On 31 October it sits 2.2° south-southeast of mag. +4.3 Botein (Delta (δ) Arietis).

Neptune

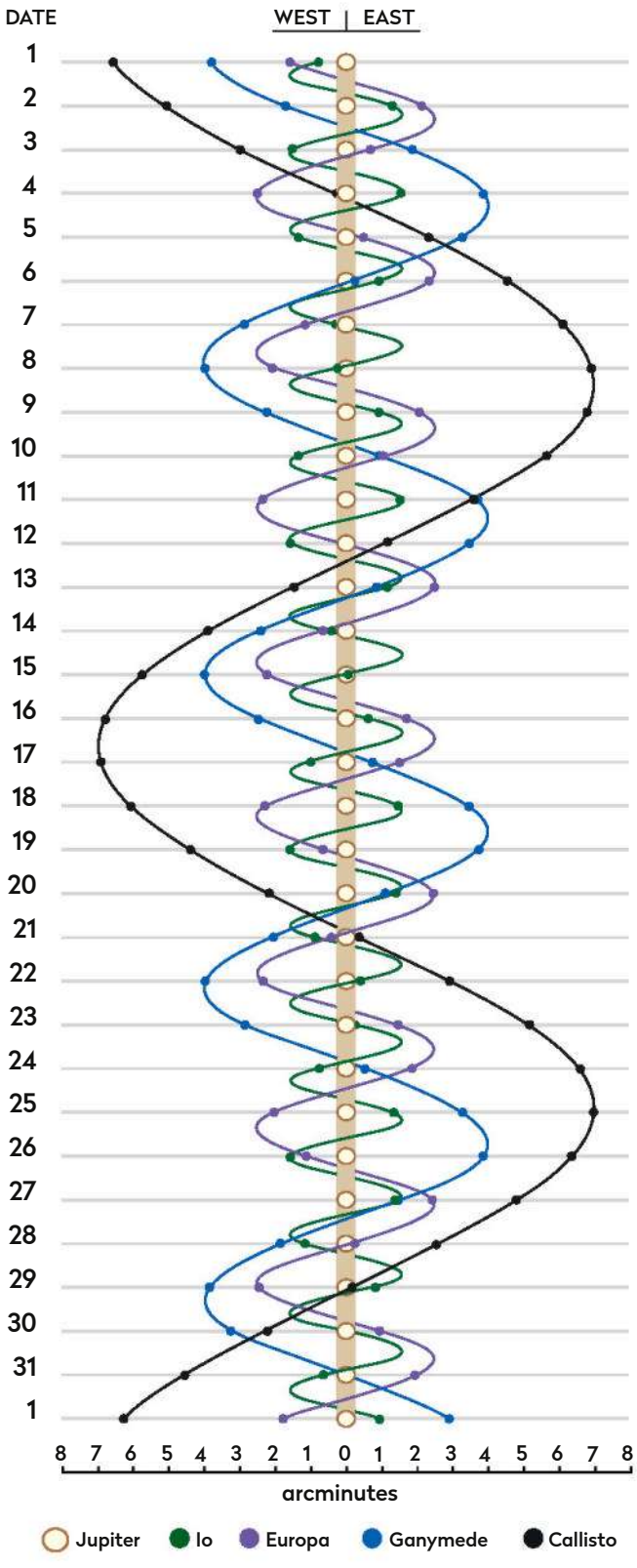
Best time to see: 2 October, 00:15 BST (1 October 23:15 UT)
Altitude: 34°
Location: Pisces
Direction: South

An evening planet, favourably placed, Neptune reaches a peak altitude of 34° under dark sky conditions all month. It currently shines at mag. +7.9.

MORE **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: OCTOBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – OCTOBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

1 October at 01:00 BST
15 October at 00:00 BST
31 October at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in October*

Date	Sunrise	Sunset
1 Oct 2023	07:11 BST	18:48 BST
11 Oct 2023	07:29 BST	18:24 BST
21 Oct 2023	07:48 BST	18:01 BST
30 Oct 2023	07:06 UT	16:40 UT

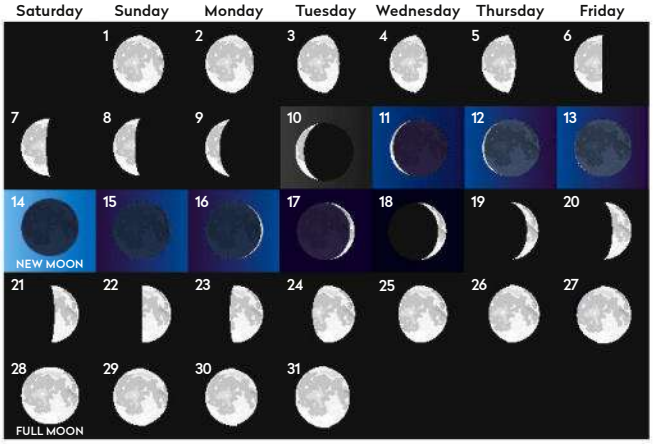
Moonrise in October*

Moonrise times

1 Oct 2023, 19:27 BST	17 Oct 2023, 11:04 BST
5 Oct 2023, 21:27 BST	21 Oct 2023, 15:41 BST
10 Oct 2023, 02:09 BST	25 Oct 2023, 17:00 BST
13 Oct 2023, 05:51 BST	29 Oct 2023, 16:47 UT

*Times correct for the centre of the UK

Lunar phases in October



MORE **ONLINE**

Paul and Pete's night-sky highlights

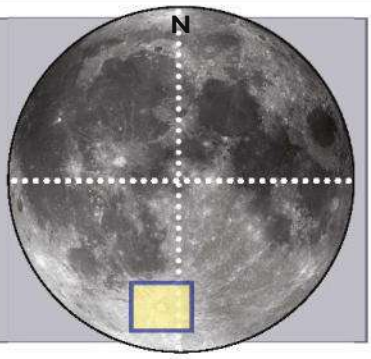
Southern Hemisphere sky guide

MOONWATCH

October's top lunar feature to observe

Tycho

Type: Crater
Size: 86km
Longitude/latitude: 11.2° W, 43.3° S
Age: Less than 1.1 billion years
Best time to see: 1 day after first quarter (22–23 October) or last quarter (7–8 October) and at full Moon (28 October)
Minimum equipment: 50mm refractor



Tycho is one of the most recognisable features on the Earth-facing side of the Moon. Superbly detailed when seen under oblique lighting, it's also a showpiece when the Moon's phase places it under direct lighting. During full Moon, for example, Tycho and its rays are very obvious.

This is largely due to Tycho's youthful age. Its formation sent vast arcs of ejecta heading across the Moon's surface. When this material finally settled, it formed the huge rays we see today. The rays remain bright and obvious, something that will change over time as they become dulled by the solar wind. At present, they form a system that conveniently points back towards Tycho: a navigational aid hard to miss.

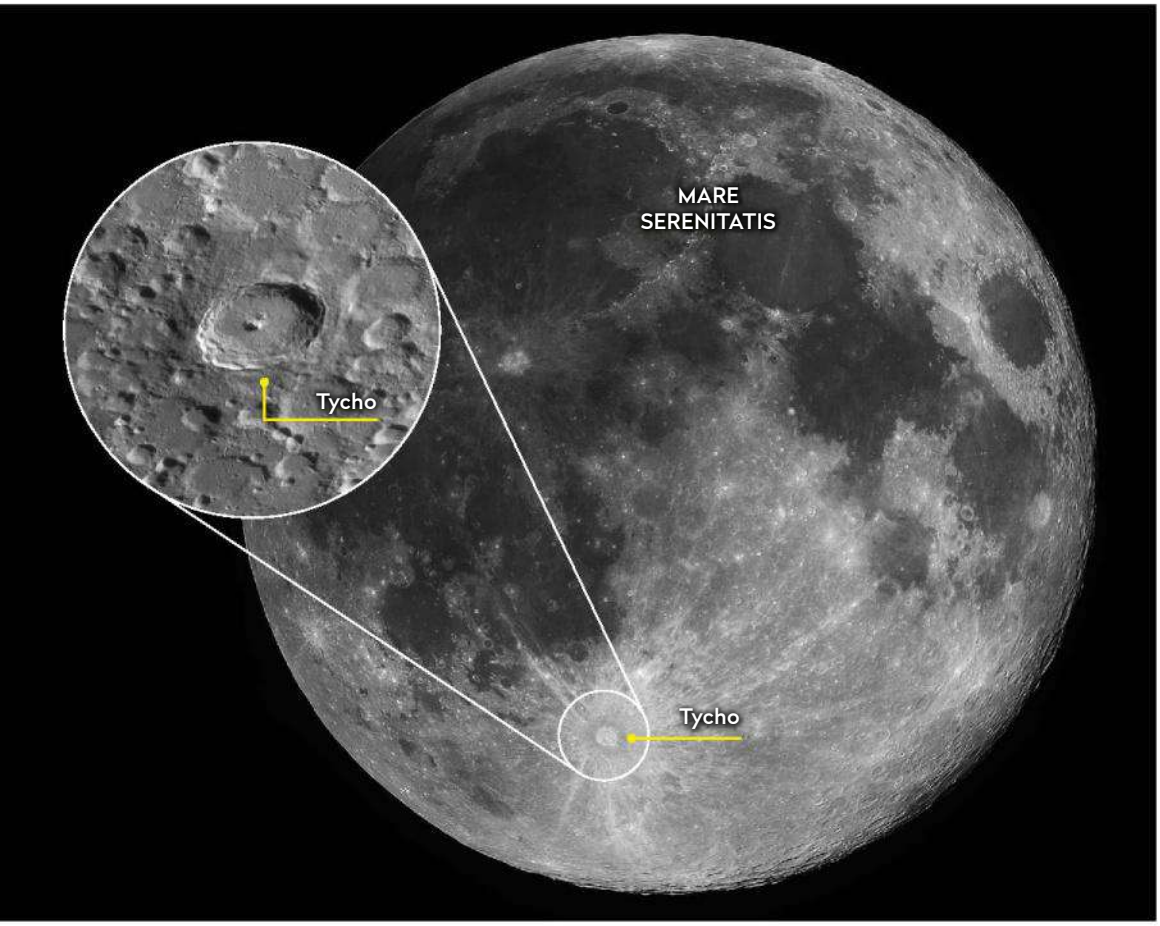
Tycho is around 86km across, appearing crisp and sharp with no rim or floor incursions. It's a classic lunar crater, a circular formation surrounded by a distinct rampart collar which helps separate the crater from the heavily cratered and complex highland region in which it's located. The outer ramparts climb steadily to the rim edge, which shows peak heights to the east and west rising approximately 5.2km above the crater's floor. On average, the rim sits about 4.6km above Tycho's floor. As you move down towards the crater floor, you encounter finely detailed terraces around the whole perimeter of the internal rim.

Eventually, the terraces give way to a roughly circular floor area 54km in diameter. In the centre sits a framed central mountain complex, the peaks of which rise to around 1.5km above the surrounding floor surface. Tycho's floor appears textured, something that is more apparent when the Sun is low in its sky and the lighting oblique. The northeast quadrant appears less textured and smoother than the remaining three-quarters.

Although at first glance Tycho looks relatively symmetrical, there are subtle asymmetries. The shape of the impact melt, outer rampart collar and distribution of the impressive ray system hint at an oblique impact. The slope of the eastern rim is also around 12° steeper than that found to the west.

It's an interesting exercise tracing Tycho's rays across the lunar surface, best carried out during the fuller phases. Under such lighting the impact melt collar appears darker than the surrounding highland surface and Tycho's interior, really resembling a collar. Beyond this, the rays spread across the highland regions to eventually reach dark mare lava. This gives them an extended lease of life, their lighter material contrasting well with dark mare surfaces. Look for one extremely prominent ray heading north-northeast, eventually passing up to Mare Serenitatis. It crosses the entirety of the mare and continues beyond. In total it appears to extend over 3,000km from Tycho.

It's testament to the impact that created Tycho around 1.1 billion years ago that the crater is so prominent despite being located in one of the most heavily cratered regions of the Moon.



PETE LAWRENCE X 3

▼ **Long, bright ejecta rays point the way to crater Tycho, whose high central peak is easily seen with a small scope**

COMETS AND ASTEROIDS

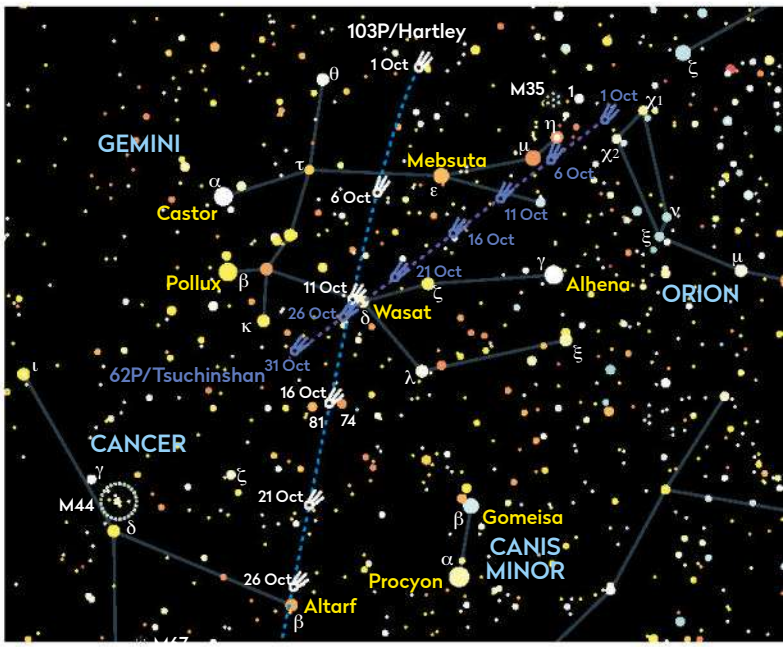
Comet Hartley 2 should be bright and high for observation all month

Comet 103P/Hartley, known as Hartley 2, is in a good position as it approaches perihelion on 12 October. At peak brightness the comet may reach mag. +8.5 but as it was relatively close to Earth in late September, it'll probably appear large and diffuse.

Hartley 2 is a morning object during October, its month track beginning in Auriga but quickly passing into Gemini. It crosses the main form of the stick-figure twins between 5 and 11 October, lying very close to mag. +3.5 Wasat (Delta (δ) Geminorum) on the night of 10/11 October.

As this coincides with the comet approaching peak brightness, the early hours of 11 October should be a good time to look for it. The only negative is the Moon in Leo, 9° east of Venus. This shouldn't be too much of an issue, though, as it will be at a slender 11%-lit waning phase. In addition, observing before 03:00 BST (02:00 UT) puts the comet at a decent altitude and the Moon below the horizon. The Moon rises around 03:30 BST (02:30 UT) on this date.

After its close pass of Wasat on 10/11 October, Hartley 2 heads southeast to eventually cross the border with Cancer on 19 October. Its track takes it very close to Altarf (Beta (β) Cancri) on the morning of 27 October. The period up to 27 October is optimal for observing Hartley 2 as this will allow you to view the comet without the Moon spoiling the view. Be aware that the Moon does set just as astronomical dawn is about to start on 27 October. Based on previous apparitions, Hartley 2 should remain close to peak brightness throughout October.



▲ **Hartley 2 is best seen in pre-dawn skies as it drops through Gemini**

STAR OF THE MONTH

Markab, the 'saddle' in an iconic autumn asterism

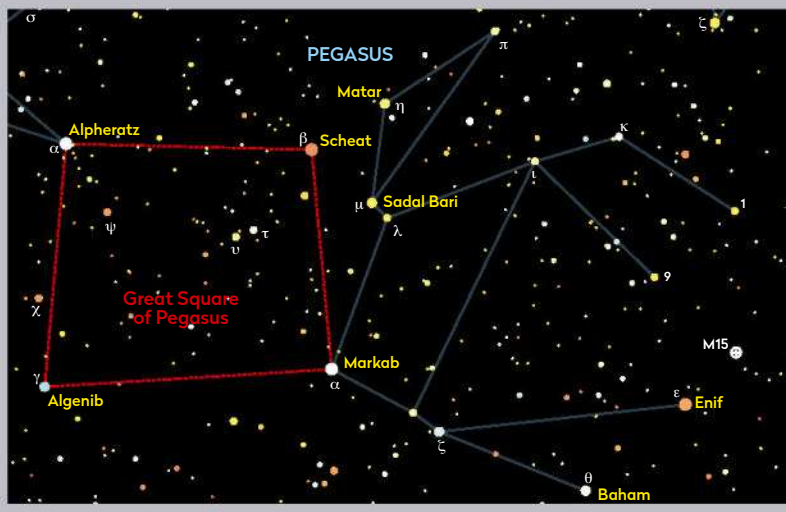
Markab (Alpha (α) Pegasi) is one of the four corner stars of the Great Square of Pegasus, the one that marks the southwest corner to be precise. It's the third brightest in the Square, shining at mag. +2.5. Magnitude +2.1 Alpheratz (Alpha (α) Andromedae) in the northeast and mag. +2.4 Scheat (Beta (β) Pegasi) in the northwest are a little brighter, while mag. +2.8 Algenib (Gamma (γ) Pegasi) in the southeast is the faintest.

The name Markab derives from the Arabic for 'saddle of the horse'. In Chinese culture it forms an asterism with Scheat called the encampment, Markab being the 'first star of the encampment'.

The Square stars are white with the exception of Scheat, which appears orange. Markab is an evolved subgiant star of spectral classification A0 IV. This means its core hydrogen has run out and the fusion of this element has stopped, or is in the process of stopping. Just to show how close to the tipping point Markab is, its spectrum is sometimes given as B9 V or B9.5 III – that's a hot blue-white dwarf or giant.

Markab is estimated to be 133 lightyears away and has a mass 3.5 times, radius 4.6 times and luminosity 165 times larger than our own Sun. It's a fast rotator too, at 130 km/s.

▼ **Markab (Alpha Pegasi) forms one corner of the Great Square of Pegasus**

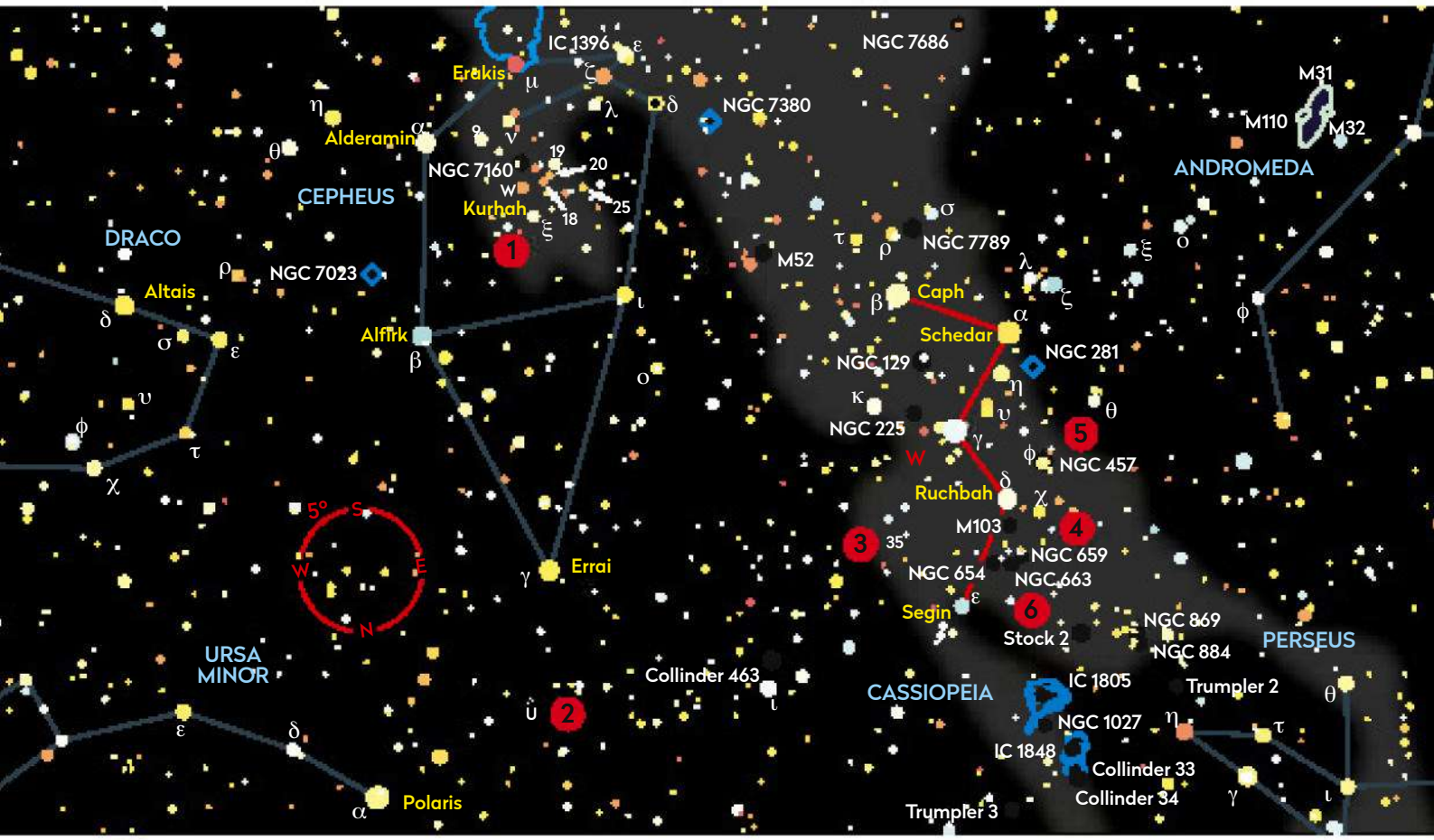


The star is remarkable for not being remarkable, a normal star with no real deviations from what you'd expect from it. As a consequence, it has been cited many times as a standard against which other stars are measured.

BINOCULAR TOUR

With Steve Tonkin

Wrestle a muscleman and do some bird-watching in our look around Cassiopeia



1. Kurhah star field

10x 50 The very white mag. +4.4 Kurhah (Xi (ξ) Cephei) is the most northerly and brightest star of a lovely group that stretches southward for about 3°. There are some very red stars like mag. +5.2 18 Cephei and, at the other extreme, hot blue mag. +5.1 19 Cephei. Give yourself time to appreciate the sheer variety of what's on show and look around for the other, fainter groups of colourful stars that lurk nearby. ☐ **SEEN IT**

2. U Cephei

10x 50 Eclipsing variable star U Cephei lies midway between two white mag. +5.6 stars, 7.5° from mag. +2.0 Polaris (Alpha (α) Ursae Minoris) in the direction of mag. +2.1 Gamma (γ) Cassiopeiae. Its magnitude range is +6.8 to +9.2, a nine-fold variation in brightness over a period of 2.5 days which, coupled with it being circumpolar from the UK, makes it a suitable subject for newcomers to variable star observing. ☐ **SEEN IT**

3. 35 Cassiopeiae

10x 50 If you imagine that Segin (Epsilon (ε) Cassiopeiae) and Ruchbah (Delta (δ) Cassiopeiae) and Gamma (γ) Cassiopeiae are the apexes of a rhombus, you'll see a triangle of stars near the fourth apex. The one nearest to Segin is mag. +6.3 35 Cassiopeiae, a very white star, but can you detect any colour in its mag. +8.4 companion 1 arcminute to the north? This is a line-of-sight pairing, not a true binary star. ☐ **SEEN IT**

4. The Cassiopeia triple cluster (NGC 654, 659, 663)

15x 70 Look 1° to the east of the middle of an imaginary line joining Segin and Ruchbah and you'll easily find the largest and richest of these clusters, NGC 663. Slightly less than 1° to the north-northwest is the brighter but smaller NGC 654. The poorest of the trio is NGC 659, a tiny ghostly glow which may need averted vision, just on the NGC 663 side of mag. +5.8 44 Cassiopeiae. ☐ **SEEN IT**

5. The Owl Cluster, NGC 457

15x 70 Start at Ruchbah and navigate 2° southwest to mag. +5.0 (Phi (φ) Cassiopeiae) and its mag. +7.0 companion 2 arcminutes further on. These are the owl's eyes. Its body and wings are ninth and 10th-magnitude stars that span an area about 0.25° in the direction of Gamma Cassiopeiae. The brighter eye is not actually part of NGC 457; it lies half-way between us and the 8,000-lightyear-distant cluster. ☐ **SEEN IT**

6. The Muscleman Cluster

10x 50 Identify the Perseus Double Cluster (NGC 884 and NGC 869) and from the part nearest to Cassiopeia follow a 2° chain of eighth-magnitude stars north to Stock 2, the Muscleman Cluster. This gets its name from the brighter stars having the form of a stick-man in muscle-flexing body-builder pose, ripping this star-chain away from the Double Cluster. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 2

THE SKY GUIDE CHALLENGE

Can you capture colours in the shadow of this month's slender lunar eclipse?

A total eclipse of the Moon is typically quite colourful. What you would expect to be a totally dark shadow of Earth is infilled with light refracted through our planet's thin skin of atmosphere. This not only brings light to the otherwise dark shadow, but it also brings colour from what is essentially a continuous ring of sunrise and sunset as seen from the vantage point of the Moon. The red colouration is obvious when the Moon is completely covered by Earth's shadow, but can it be seen or photographed during a partial eclipse? This is the subject of this month's challenge.

If it's clear on 28 October, from the UK we'll be able to see a slender portion of the Moon's disc covered by the darkest, umbral, portion of Earth's shadow. Turn to page 46 to find additional details and timings. Both the umbral shadow and the penumbral shadow contain colour, but the presence of the bright lunar surface makes this nigh on impossible to see and very hard to photograph.

An additional difficulty comes from the colour itself, which can vary quite a lot between eclipses. A dark eclipse can become a deep, ruddy, brown colour, which makes the Moon quite hard to see against a dark sky. A light eclipse, on the other hand, may appear a bright coppery colour. The variation occurs due to the amount of cloud present in the thin layer of Earth's atmosphere that light has to pass through during the eclipse.

A camera is the best way to record this colour, but you'll have to work at producing a high-dynamic-range (HDR) image. This can be produced either with a colour camera or a monochrome camera with switchable red, green and blue (RGB) filters. If you have both, the mono camera can be used to capture the luminance or tonal aspect of the eclipse, the colour camera being used to record the colour information. A pseudo luminance can be created by using the colour camera to capture an image, subsequently using your graphics editor to convert it to greyscale. Using a layer-based editor, carefully align images and, with the greyscale image on top, set its blend mode to luminance.

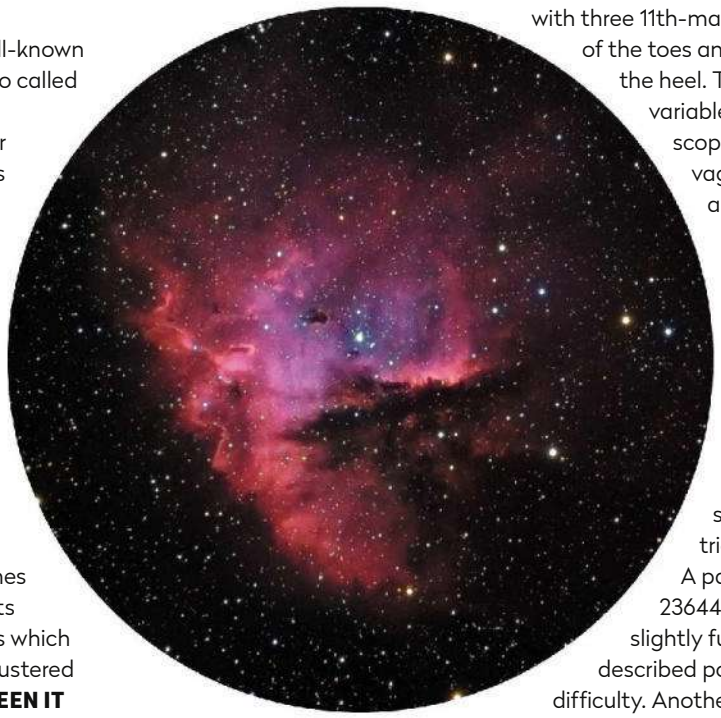
The beauty of this challenge is that once you've grabbed the exposures required, you can take your time to create a composed HDR image which hopefully looks natural and brings out the colourful beauty of this small but exciting eclipse. It should certainly be possible to extract the umbra's colour, but can you pick out any banding in the adjacent penumbra?

Correctly exposed for the lighter areas of the Moon (mono or colour converted to greyscale)
Correctly exposed for the eclipsed portion (colour)
Greyscale correctly exposed version aligned and layered over colour version as a luminance layer
Colour layer's saturation increased with a blur applied, greyscale curves tweaked

▲ Processed images of a partial lunar eclipse from 2013 combined to create a high-dynamic-range (HDR) result that shows umbral colour. Note that the partial lunar eclipse that's happening on 28 October will affect the southern portion of the Moon's disc

DEEP-SKY TOUR

Enjoy hunting down five clusters and a nebula in the western half of Cassiopeia



▲ **Game on: can you find the gaping mouth of the Pacman Nebula, NGC 281, our final target in this month's tour?**

SEBASTIAN VOLTMER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 NGC 7789

We start with the well-known cluster NGC 7789, also called the White Rose Cluster or more commonly Caroline's Rose, after discoverer Caroline Herschel. It's located 2.9° southwest of Caph (Beta (β) Cassiopeiae), one of the points forming a right-angled triangle together with Schedar (Alpha (α) Cassiopeiae), Caph being at the right angle. It has an integrated magnitude of +6.7 and appears around 20 arcminutes across through a 150mm scope with over 50 members resolved. A 300mm scope resolves around three times as many stars. The 'Rose' gets its name from curving lines of stars which give the impression of petals, clustered around the flower's centre. ☐ **SEEN IT**

2 M52/NGC 7635

Our next target is 6.5° northwest of NGC 7789. Locate mag. +4.9 4 Cassiopeiae and 0.7° to the south you'll find the Salt and Pepper Cluster, M52. Listed at mag. +6.9, a 150mm scope shows a hazy patch with around 30 individual stars scattered over a 10-arcminute region, a number that triples through a 300mm scope. While looking at M52, observe the region 0.5° southwest. Here lies NGC 7635, a region of diffuse nebulosity. A 150mm scope may struggle, but a 250mm scope should show it as a glowing patch around 1 arcminute across. This is the Bubble Nebula, so-called because of the ring structure visible in long-exposure photographs, representing the edge of a giant bubble blown in the nebula by the star SAO 20575. ☐ **SEEN IT**

3 NGC 7790

Head 4.5° east from M52 and you'll arrive at another open cluster, NGC 7790. Alternatively, look 2.5° northwest of Caph. This cluster is fainter than Caroline's Rose, with an integrated magnitude of +8.5. It's considerably smaller too, a 150mm scope revealing a compact object around 4 arcminutes across. Under suburban skies, it appears as a hazy glow, giving the impression of a footprint with three 11th-magnitude stars marking some of the toes and a mag. +10.2 one marking the heel. The northern 'toe' is Cepheid variable CF Cassiopeiae. A 250mm scope resolves around 25 stars in a vaguely rectangular area of 4 x 2 arcminutes. ☐ **SEEN IT**

4 NGC 129

To locate NGC 129, imagine the line between Caph and Gamma (γ) Cassiopeiae, the mag. +6.5 cluster being slightly on the Caph side of the mid-point. Through smaller instruments, this is tricky to see as it's pretty sparse. A pair of red stars (mag. +8.8 HD 236446 and mag. +8.6 HD 236449) slightly further east along the line described point at it, in case you're having difficulty. Another pointer is HD 2377 at mag. +5.9, located 0.25° south of the cluster's centre. A 300mm scope shows around 50 stars in an area 15 arcminutes across, three 10th-magnitude members forming a distinctive, almost equatorial, triangle in the cluster's centre. ☐ **SEEN IT**

5 NGC 189

Next up is the tricky cluster NGC 189, which lies 1.5° east-northeast of NGC 129. Alternatively, find it 2.1° west and a fraction north of Gamma Cassiopeiae. It's a poorly concentrated object with an integrated magnitude of +8.8. It's also relatively small, contained in an area 3.7 arcminutes across. To see it properly be prepared to up the magnification. There's a square asterism adjacent to it. With a bit of imagination, a fifth star forms a pattern with the square, not dissimilar to the 'house' asterism that forms most of Cepheus. Smaller instruments show a haze with a few resolved members, while a 250mm scope shows 20 or so stars in the area. ☐ **SEEN IT**

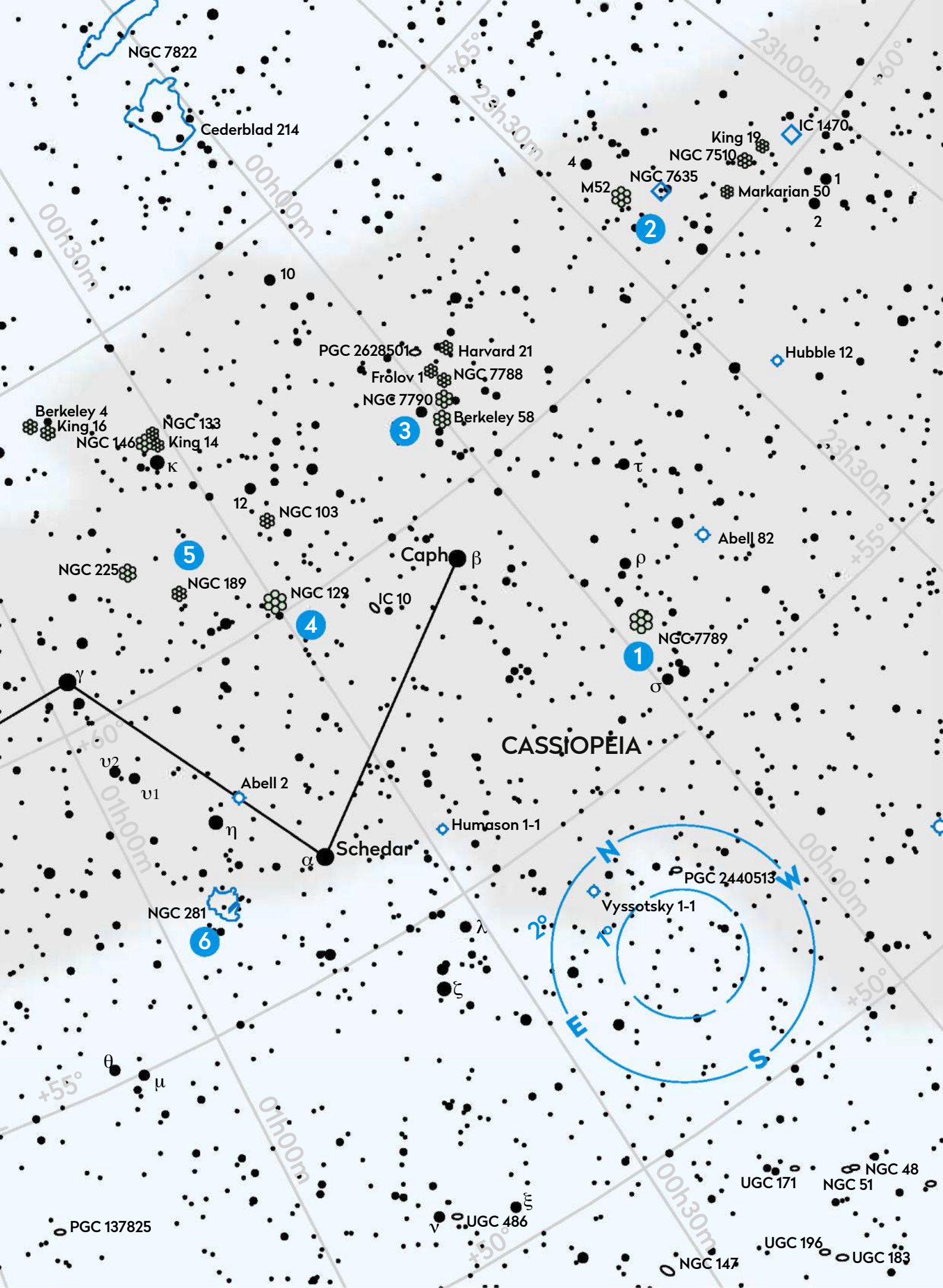
6 NGC 281

Our last target is nebula NGC 281, 0.5° west and 4.1° south of Gamma Cassiopeiae or, if you prefer, 1.7° east of Schedar. A 150mm scope shows a nebulous glow around 11 arcminutes across. Four brighter stars appear within the nebula boundary, along with a scattering of fainter ones. The middle star is interesting as it splits into several components with powers over 100x. Long-exposure photos reveal a dark lane crossing the nebula which, together with a small dark patch forming an eye, look like a basic sideways face. This gives NGC 281 its informal name, the Pacman Nebula. ☐ **SEEN IT**

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions


NGC 7822
Cederblad 214
King 19
IC 1470
NGC 7510
4
NGC 7635
M52
Markarian 50
1
2
2
10
PGC 2628501
Harvard 21
Hubble 12
Frolov 1
NGC 7788
NGC 7790
Berkeley 58
3
Berkeley 4
King 16
NGC 133
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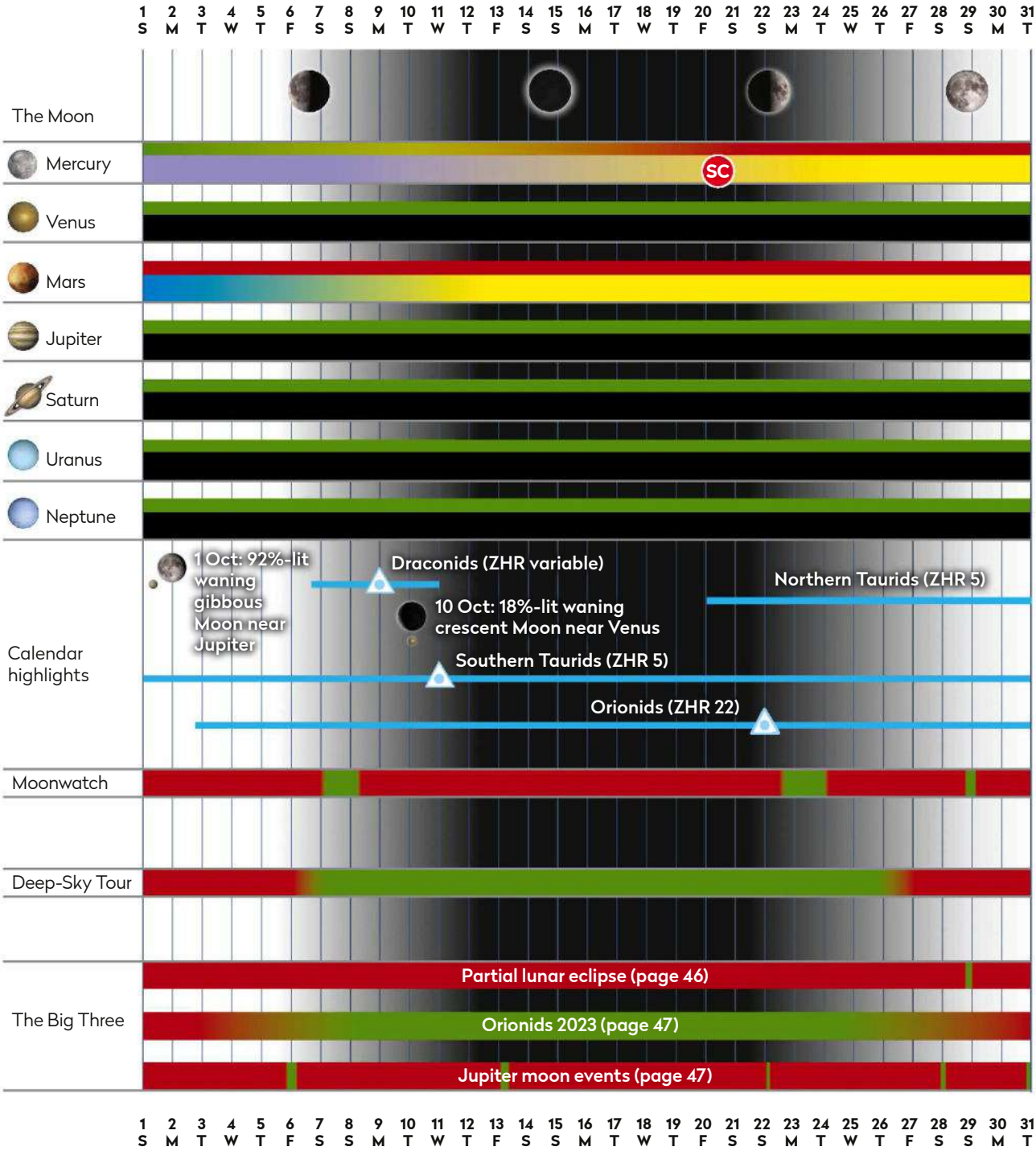
NGC 51
UGC 196
UGC 183
NGC 147
23h00m
23h30m
00h00m
00h30m
01h00m
01h30m
+65°
+60°
+55°
+50°

AT A GLANCE

How the Sky Guide events will appear in October


1 S 2 M 3 T 4 W 5 T 6 F 7 S 8 S 9 M 10 T 11 W 12 T 13 F 14 S 15 S 16 M 17 T 18 W 19 T 20 F 21 S 22 S 23 M 24 T 25 W 26 T 27 F 28 S 29 S 30 M 31 T
The Moon
Mercury
SC
Venus
Mars
Jupiter
Saturn
Uranus
Neptune
Calendar highlights
1 Oct: 92%-lit waning gibbous Moon near Jupiter
Draconids (ZHR variable)
10 Oct: 18%-lit waning crescent Moon near Venus
Northern Taurids (ZHR 5)
Southern Taurids (ZHR 5)
Orionids (ZHR 22)
Moonwatch
Deep-Sky Tour
The Big Three
Partial lunar eclipse (page 46)
Orionids 2023 (page 47)
Jupiter moon events (page 47)
1 S 2 M 3 T 4 W 5 T 6 F 7 S 8 S 9 M 10 T 11 W 12 T 13 F 14 S 15 S 16 M 17 T 18 W 19 T 20 F 21 S 22 S 23 M 24 T 25 W 26 T 27 F 28 S 29 S 30 M 31 T

KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction

- Full Moon
- First quarter
- Last quarter
- New Moon

CHART BY PETE LAWRENCE

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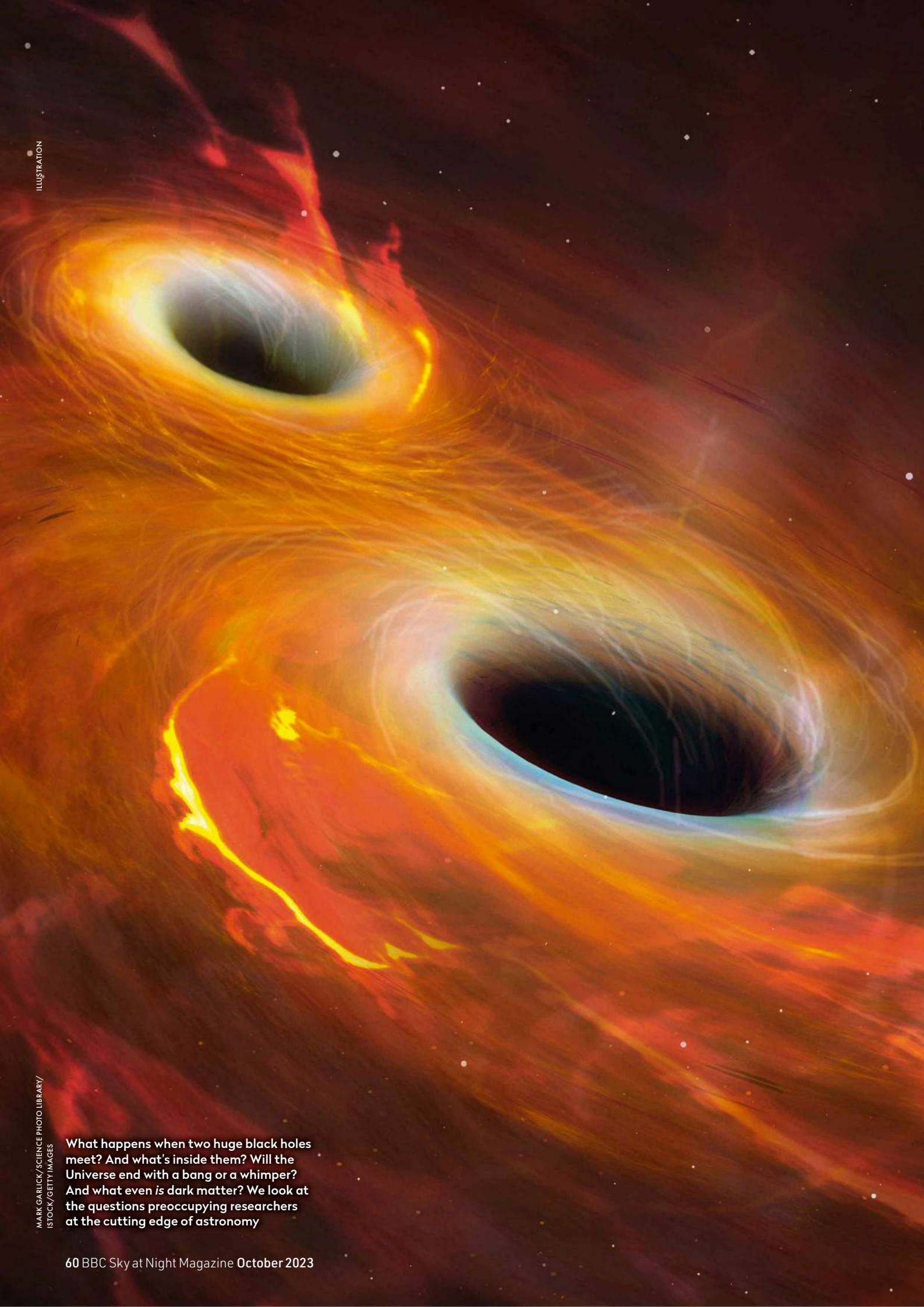


ILLUSTRATION

MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES

What happens when two huge black holes meet? And what's inside them? Will the Universe end with a bang or a whimper? And what even *is* dark matter? We look at the questions preoccupying researchers at the cutting edge of astronomy

What we still don't know about the UNIVERSE

Edwin Hubble solved a really big one but, 100 years on, **Colin Stuart** looks at what cosmic conundrums still have astronomers scratching their heads

On 6 October 1923, the American astronomer Edwin Hubble used the 100-inch Hooker Telescope at the Mount Wilson Observatory in California to photograph the Andromeda Galaxy. The calculations that resulted solved one of the biggest unanswered astronomical questions of the day by proving that Andromeda, and other 'spiral nebulae' like it were actually huge galaxies millions of lightyears away, rather than small objects closer by, within the Milky Way. The discovery changed astronomy forever by showing just how vast our Universe truly is.

Exactly a century later, technology may have massively improved, but there are still many unsolved mysteries surrounding our Universe. Here are some of the most pressing issues occupying the finest astronomical minds of the 21st century.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at colinstuart.net/ebook

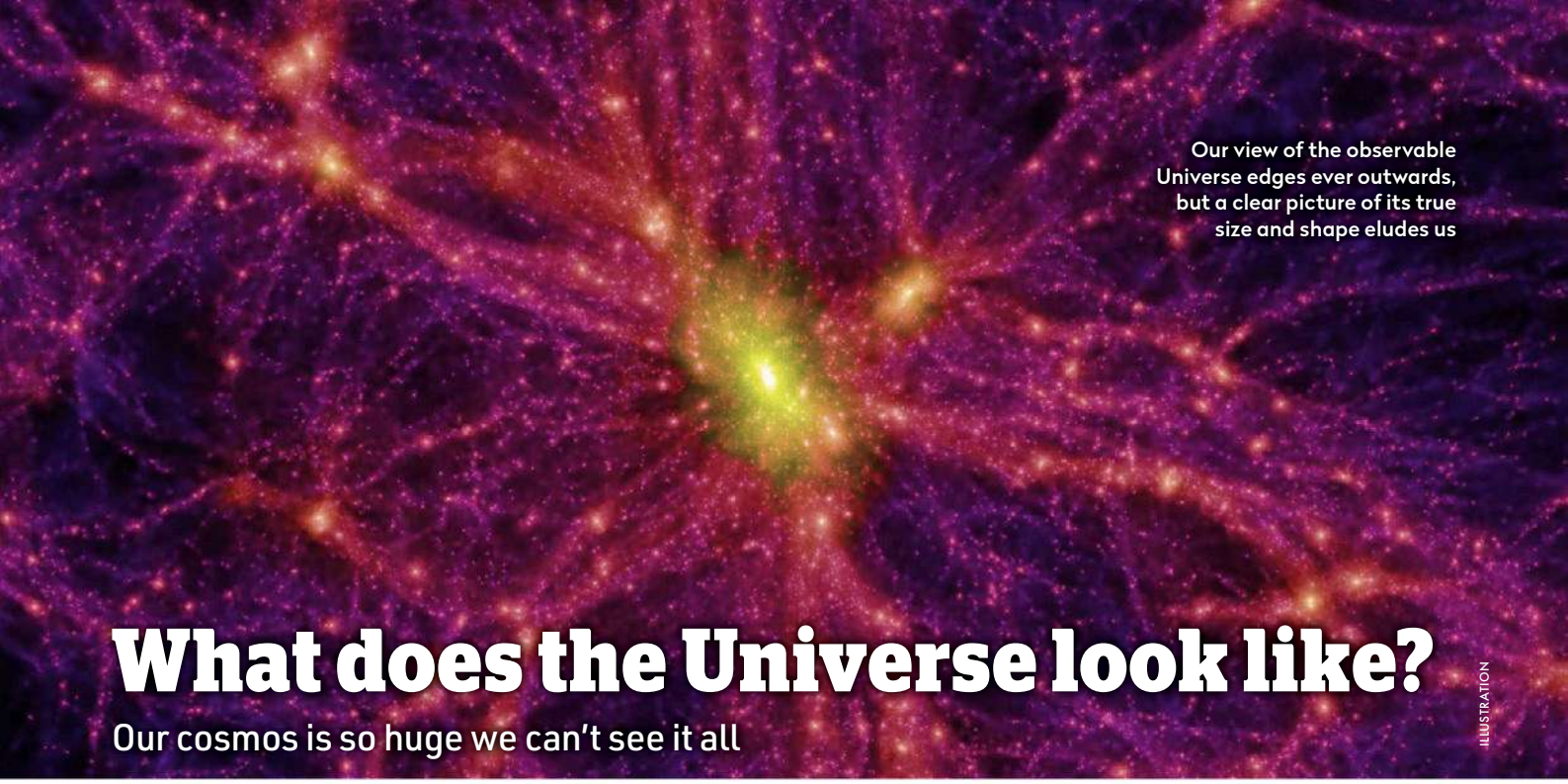
How do supermassive black holes merge?

When black holes get too close to each other, they could end up dancing in circles

When a black hole smashes into another black hole, it sends shock waves rippling out through space itself: gravitational waves. Yet so far the mergers we've seen have come from so-called stellar-mass black holes – those with masses a few tens of times the mass of our Sun. That's tiny compared to a supermassive black hole, which can tip the scales at billions of solar masses.

There's a supermassive black hole in the centre of every major galaxy and galaxies also collide, so what happens to the two black holes at their hearts? You'd think that they'd merge too, but there's a problem. To spiral inwards, the black holes need to lose energy, which they do by shedding heat to surrounding gas, dust and stars. Yet when they get within a parsec of each other – about 3.26 lightyears – there's no longer enough stuff to lose energy to. This 'final parsec problem' means the supermassive black holes should remain orbiting each other and never actually merge.

However, recent evidence from the NANOGrav experiment suggests that the Universe is humming with gravitational waves from supermassive black hole mergers. The data from this hum might give astronomers the clues they need to finally unpick this problem. ▶



Our view of the observable Universe edges ever outwards, but a clear picture of its true size and shape eludes us

What does the Universe look like?

Our cosmos is so huge we can't see it all

ILLUSTRATION

Look at the large-scale structure of the Universe today and countless galaxies are strung out on endless filaments in a cosmic web. It seems that tiny variations in density in the very early Universe acted as seeds from which this structure eventually blossomed. Over-dense regions drew in more and more material to create galaxy-filled superclusters and leave behind supervoids.

Except the Big Bang theory says that the early Universe should have been completely smooth. How come it had tiny imperfections of just a few parts in one hundred thousand, but which created the Universe as we see it today?

One explanation is a modification to the Big Bang, called inflation. It argues that the Universe underwent a period of super-rapid expansion in the first miniscule fraction of a second. The cosmos went from considerably smaller than an atom to about the size of a grapefruit in a trillionth of a trillionth of a trillionth of a second.

Before this, the Universe was so small that it was dominated by minute quantum variations. The ensuing explosion in size blew up those variations. It's worth saying that currently there's no evidence that inflation really happened, although it does help solve other problems with the Big Bang too. Nor do we know the Universe's true size. Astronomers speak about the observable Universe – a spherical region 13.8 billion lightyears in all directions where light has had time to reach us since the Big Bang. However, there could well be things beyond this cosmic horizon that are so far away the light hasn't arrived at Earth yet.

This also makes it difficult to determine what shape the Universe is. Astronomers currently believe the 4D fabric of space-time is flat, but it could simply be that inflation has smoothed out the billions of lightyears we can see, and beyond that the Universe is actually curved.

What happens inside a black hole?

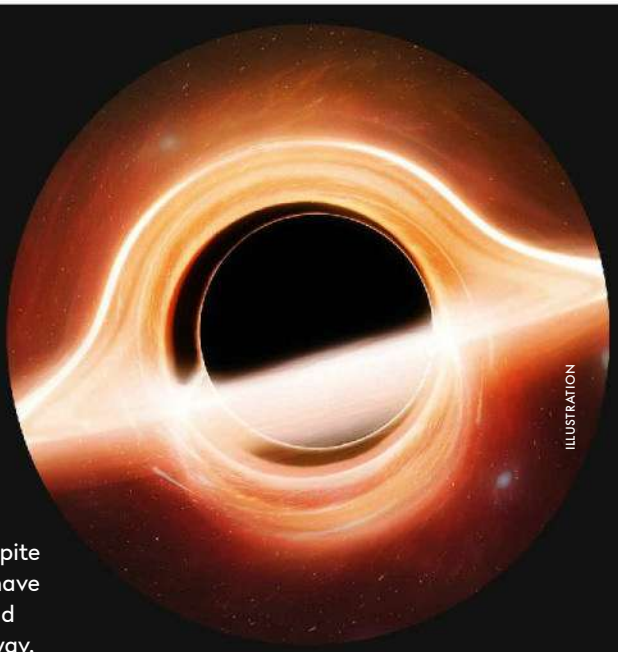
No one knows what's beyond the event horizon

Wander too close to the horizon of a black hole and the extreme difference in gravity between your head and your feet would rip you apart into lengths of human spaghetti. But where does that pasta eventually end up?

Our best theory of black holes is Einstein's general theory of relativity. It says that inside a black hole space becomes increasingly concentrated into an ever-smaller volume. In fact, at the very bottom space is crushed into an infinitely small speck called a singularity.

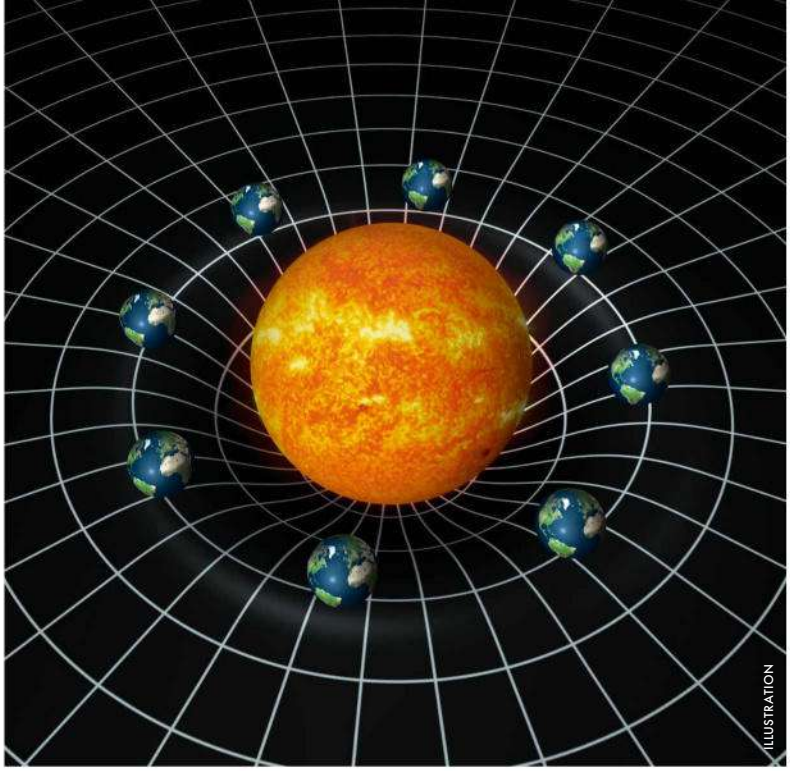
However, a singularity is likely to be a placeholder for our ignorance. The curvature of space becomes infinite and the singularity's density becomes undefined. In other words, the laws of physics suddenly lose their predictive powers.

The elephant in the room is quantum physics. If you squeeze space down into a volume smaller than an atom, then quantum physics probably has something to say on what happens. However, despite many valiant attempts, physicists have yet to combine general relativity and quantum physics in a satisfactory way. If we one day create a so-called Theory of Everything, we may find out what we need to replace a singularity with.



ILLUSTRATION

▲ Until we have a unifying Theory of Everything, black holes defy explanation

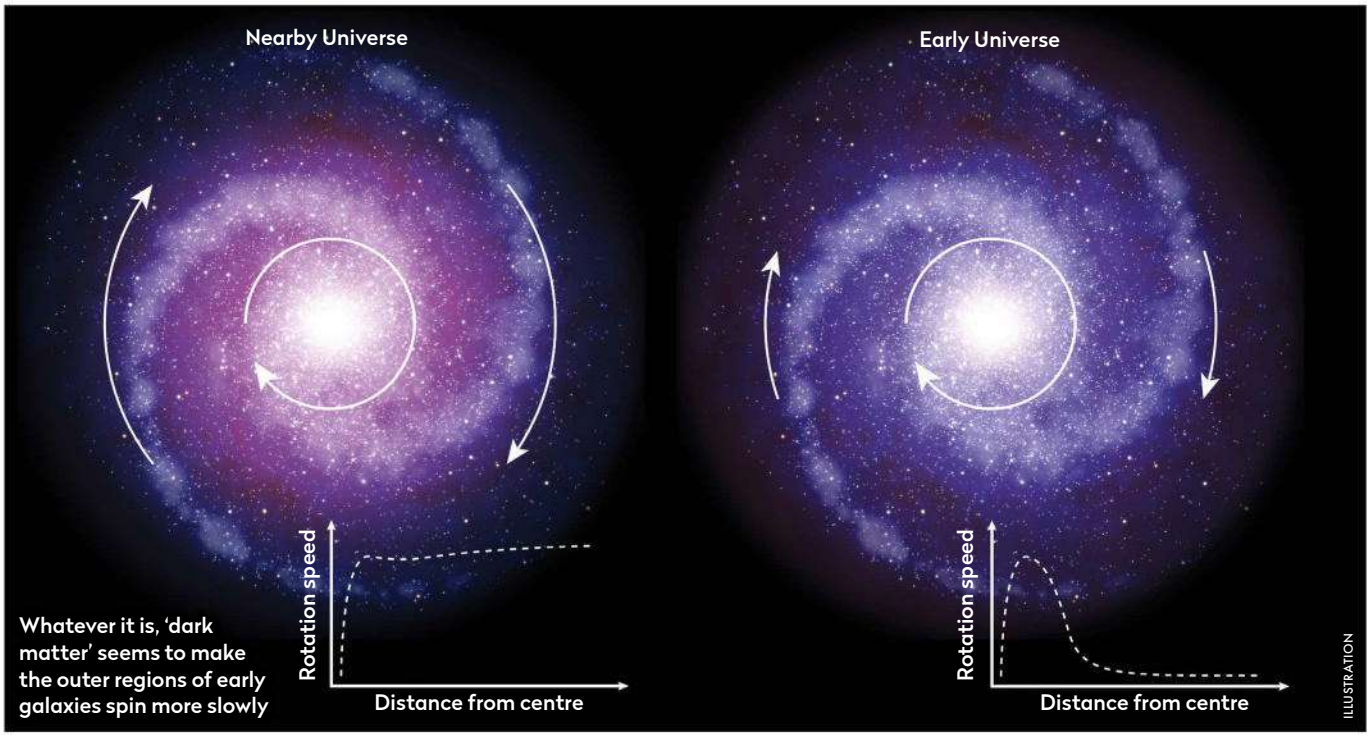


▲ **We feel the effect of apparently falling into the valley made in space-time by our Sun, but quantum physics can't as yet explain the thing we call 'gravity'**

How does gravity work?

While we know what gravity does, it's unclear how it does it

Our current best theory of gravity is Einstein's general theory of relativity. It says that massive objects like the Sun warp space-time, the fabric of the Universe, around them. Earth is then caught in the distortion that the Sun makes, which is why we orbit. Except this isn't how physicists treat any of the three other fundamental forces. They are all carried by particles called bosons. Magnets attract each other, for example, by exchanging bosons called photons. So the hunt is on for the graviton – a so-far-hypothetical particle that would be responsible for gravity.



Whatever it is, 'dark matter' seems to make the outer regions of early galaxies spin more slowly

What is dark matter?

The invisible substance keeps the Universe from flying apart

There's something about galaxies that just doesn't make sense – they're rotating far too fast. So fast that their outer stars should fly off into space, but that's not happening. Instead, astronomers suspect that galaxies contain an invisible gravitational glue called dark matter that helps to keep hold of those stars.

But what is dark matter made of? For decades the leading idea has been something called Weakly Interacting Massive Particles (WIMPs). Except physicists have gone to great lengths and performed extensive and exhaustive searches for them, and they haven't seen a single one.

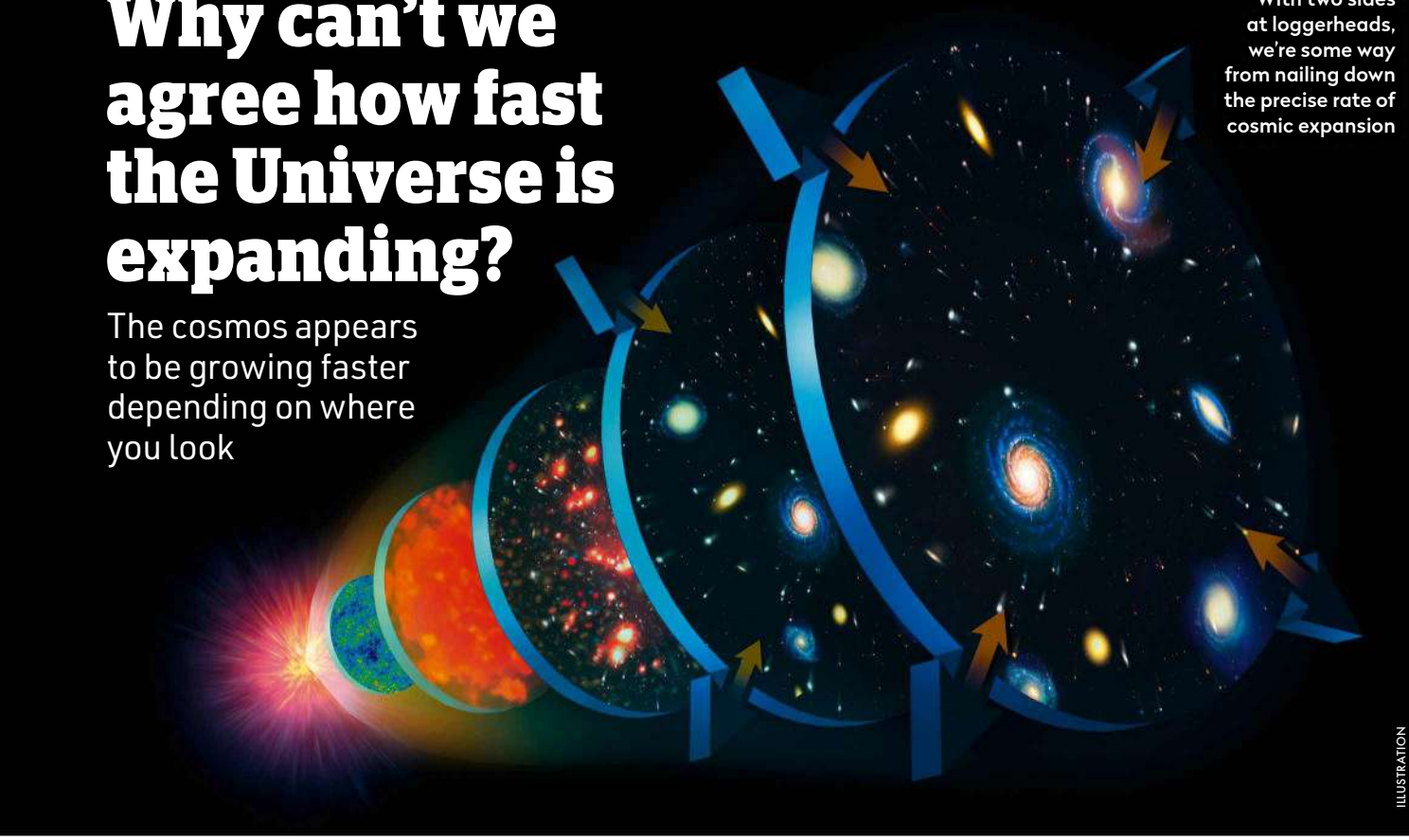
And so they're starting to look seriously at other options. Other candidates include the gravity of tiny black holes formed shortly after the Big Bang, known as primordial black holes. Or dark matter could be particles called axions, which physicists conjured up to solve a problem in particle physics.

There's a chance that dark matter isn't actually a physical substance at all, but an illusion instead. This is the premise behind a theory known as Modified Newtonian Dynamics (MOND). It says that the 'missing gravity' is actually due to the fact that gravity works differently on the scale of galaxies and we've been misinterpreting the situation. ▶

SPRINGEL ET AL. (2005), MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES, CARLOS CLARIVAN / SCIENCE PHOTO LIBRARY, ESO

Why can't we agree how fast the Universe is expanding?

The cosmos appears to be growing faster depending on where you look



With two sides at loggerheads, we're some way from nailing down the precise rate of cosmic expansion

ILLUSTRATION

When Edwin Hubble discovered cosmic expansion in the 1920s, it was a major clue that the Universe began with a Big Bang – the point at which the expansion began. Hubble found that distant galaxies appear to be moving away from us faster than those nearer to us. Galaxies aren't really moving through space, though – it's the space between galaxies that's stretching as the Universe expands. The more space there was between us and a galaxy to begin with, the faster that galaxy seems to recede when that space gets bigger.

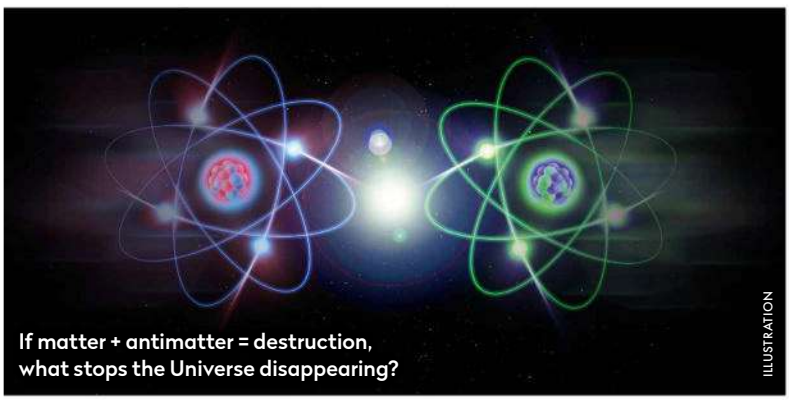
This led to the idea of a so-called Hubble constant, which measures the rate of expansion in the current Universe. When measured from objects in the nearby cosmos, it has a value of 73 kilometres per second per megaparsec (km/s/Mpc). That means a galaxy a million parsecs away (3.26 million lightyears) appears to be receding at 73 kilometres per second. A galaxy twice as far away seems to be fleeing from us twice as fast.

But there is another way astronomers can measure the Hubble constant: using the Cosmic Microwave Background (CMB). The CMB is the relic radiation left over from the Big Bang, but it can be used to calculate the current constant. However, when you do this the answer you get is 68 kilometres per second per megaparsec – about 7.5 per cent less than the value obtained from fleeing galaxies. This discrepancy has become known as the Hubble tension.

While both measurements have been verified multiple times using several different methods, it could be that one of the measurements is somehow wrong. There are also ways that both could be right – for instance, the local measurements could be skewed if we are in an unusual part of the Universe, or there could be some underlying physics we don't know about that's waiting to be discovered.

Where is all the antimatter?

The Universe should have annihilated itself long ago



If matter + antimatter = destruction, what stops the Universe disappearing?

ILLUSTRATION

Every subatomic particle has a mirror image – a particle of antimatter. When an ordinary particle meets its antimatter counterpart they annihilate in a flash of light. Matter and antimatter should have been created in equal quantities after the Big Bang and should have completely annihilated by now.

Yet the Universe is full of matter and very little antimatter. Astronomers suspect that for every billion antimatter particles, a billion and one matter particles appeared. All the antimatter annihilated with almost all the matter, leaving a tiny residue of matter. Yet we still don't know why nature has a slight preference for matter over antimatter.

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ILLUSTRATION

Which way up do galaxies form?

We could be close to finding if galaxies start small or go big from the off

Galaxies may emerge more or less fully formed or pile on the pounds by accreting matter over time – or a bit of both

There are hundreds of billions – perhaps even trillions – of galaxies in the modern Universe, but where did all these star-cities come from?

There appear to be two ways to make a galaxy. You could start small with individual stars and minor star clusters. Over time, gravity, added by the glue of dark matter, could then bind lots of these together to form the conglomerations we call galaxies. This is a so-called 'bottom-up' approach.

The alternative is 'top-down', where huge structures form early in the Universe's history only to fragment into galaxies as the cosmos aged.

The JWST is currently wowing astronomers with insights into the early Universe. It has seen fully-fledged galaxies just 400 million years after the Big Bang and even some that appear to be merging. So that seems to favour the bottom-up approach, but it needn't be a binary situation. It may be possible for some galaxies to form bottom-up, while others formed top-down.

Huge upcoming galaxy surveys like those with the Vera Rubin Observatory in Chile could help us to know more. Plus the JWST is only just getting started.

How will the Universe end?

There are several potential fates for the cosmos around us

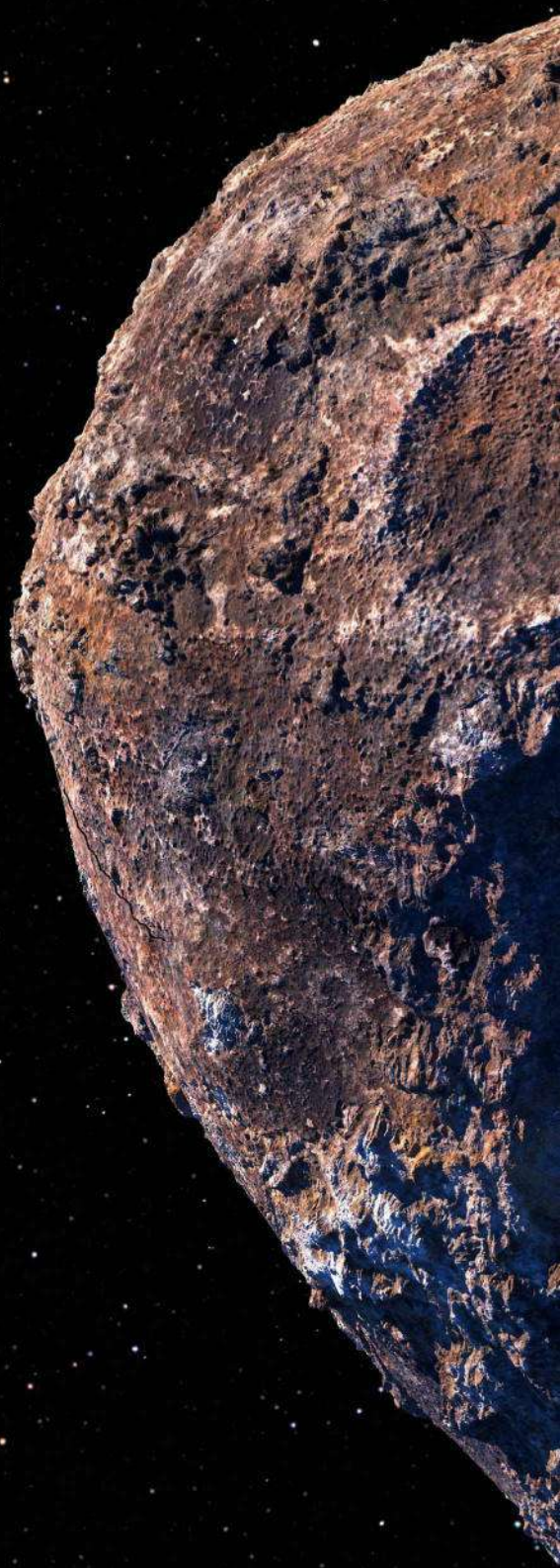
Astronomers used to think that the gravity of everything in the Universe would eventually pull the cosmos back in on itself in a reversal of the Big Bang, dubbed the Big Crunch. However, that was before they discovered that the expansion of the Universe is accelerating due to a shadowy entity known as dark energy. If it continues to accelerate, all structures in the Universe – even atoms – will be torn apart within 22 billion years in a so-called Big Rip. A more sedate expansion would lead to a Big Freeze instead, where the expansion of the Universe causes it to cool so much that stars cannot shine and the Universe eventually settles into a uniform temperature.

ILLUSTRATION

PSYCHE

Mission to a metal world

Govert Schilling explores the mystery of asteroid Psyche and how the mission to orbit it, launching this month, could unlock the secrets of the Solar System



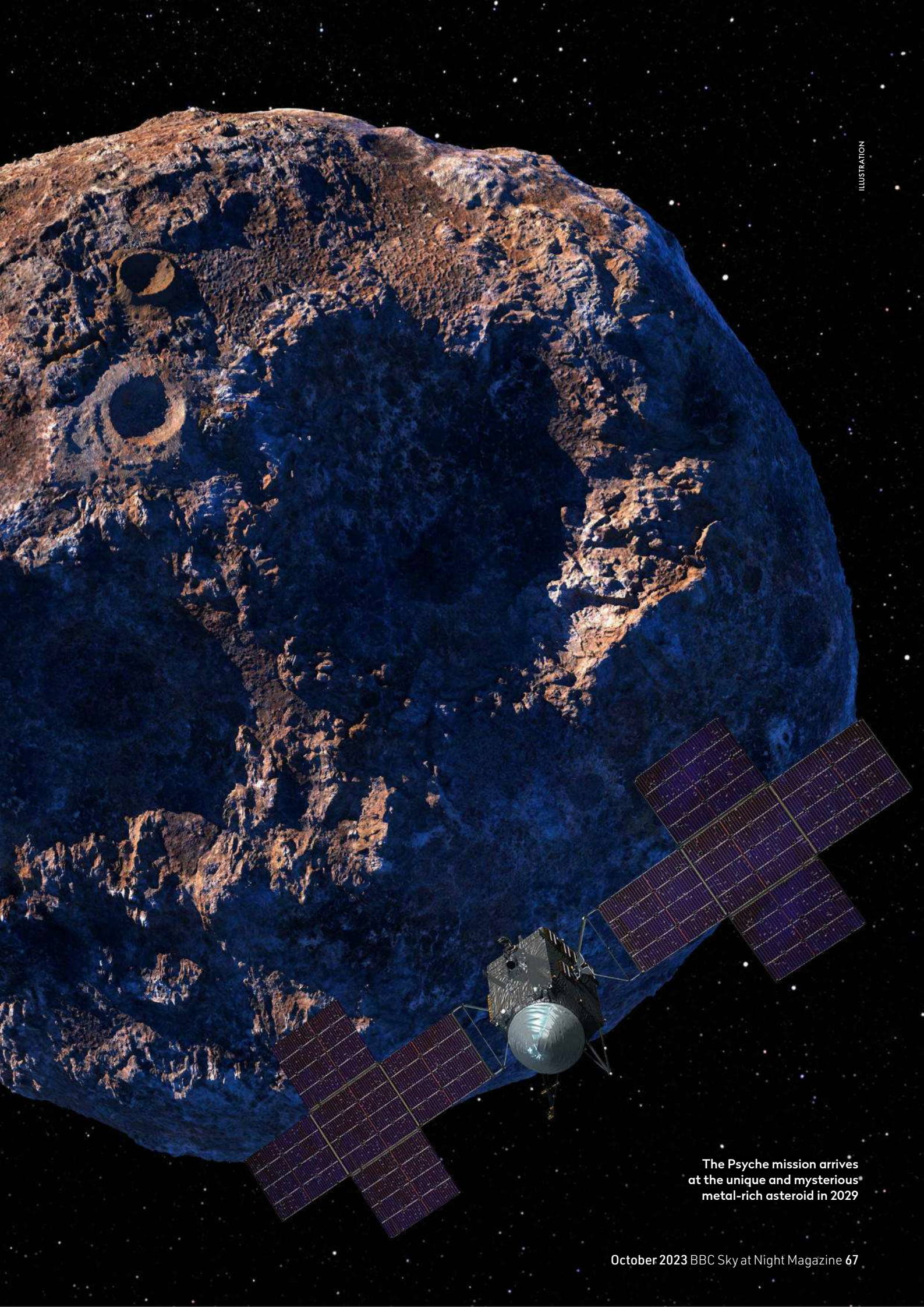
NASA/JPL-CALTECH/ASU

If the artist's impressions are anything to go by, we're in for spectacular images in August 2029, when NASA's Psyche spacecraft enters orbit around the asteroid with the same name. Psyche, slated for launch in early October, is the very first space mission to study an M-type (metallic) asteroid, and no one really knows what to expect. According to a number of recent studies, asteroid Psyche may sport volcanic 'lava' plains of pure iron or steep mountains of metal – something that has never before been seen in the Solar System.

One thing's for sure though: the Psyche mission (named after the asteroid, not the other way around!) will reveal the strange object's nature, composition and evolution, and shed further light on the origin of the Solar System. "It is our hope that Psyche teaches us about new and unexpected aspects of planet formation processes that have yet to be explored," says co-investigator Bill Bottke of the Southwest Research Institute in Boulder, Colorado. As for the asteroid itself, "we know it's metal-rich, but beyond that, its origin is an enigma."

Iron certain?

Psyche, named after the Greek goddess of the soul, was discovered 171 years ago in 1852, by Italian astronomer Annibale ▶

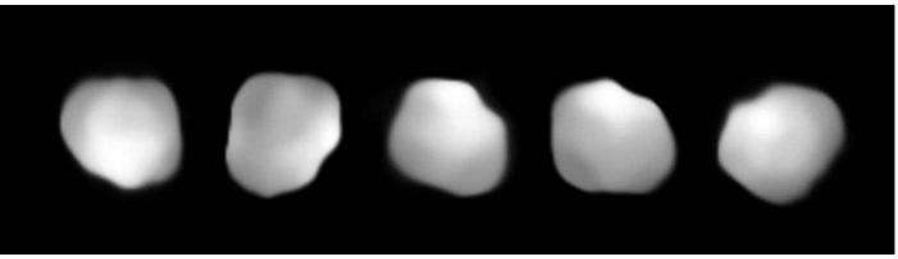


ILLUSTRATION

The Psyche mission arrives at the unique and mysterious metal-rich asteroid in 2029

◀ **Psyche could be the stripped-back metallic core left over from collisions in the early planet-forming phase of our Solar System or a remnant 'rubble pile' where metal is only scattered across the surface**

▼ **An artist's impression of Psyche's nickel-iron mountain peaks. Photos of the asteroid's true topography could be expected from August 2029**



▲ **Images taken by ESO's Very Large Telescope in 2018 gave us a sense of the asteroid's shape and size**

▶ de Gasparis. Back then, it was only the 16th asteroid known, and we now know it is among the 12 largest minor planets orbiting the Sun between Mars and Jupiter. With an average diameter of some 220 kilometres, Psyche contains about one per cent of the total mass of the entire asteroid belt. Moreover, spectroscopic studies and radar observations indicate its surface is very metal-rich. While astronomers have indeed discovered more of these M-type asteroids (including Lutetia, Kalliope and Kleopatra), Psyche is by far the largest and most massive one.

Astronomers have speculated that the large chunk of iron and nickel – if that is indeed what Psyche is – could be the exposed core of a larger proto-planet. During the smash-up and merging of smaller planetesimals (the building blocks of planets), the resulting larger bodies start out completely molten. Heavy metals sink to the core, while lighter rock floats to the top. Psyche may once have been such a 'differentiated' body. After it cooled down, a collision with another asteroid could have stripped the proto-planet of its rocky mantle, leaving a bare metal core.

While this scenario would provide a completely unique and unprecedented opportunity for scientists to study the core of a differentiated object, there are other possibilities as to the asteroid's origin. For example, if a differentiated body is completely shattered by a giant collision, part of the debris could reassemble into a huge 'rubble pile', with many metal-rich fragments ending up on the surface. Or maybe the iron on Psyche's surface is the result of a hypothesised geological process known as 'ferro-volcanism'. "The most important question we will answer is 'what is Psyche?'," says Lindy Elkins-Tanton of Arizona State University, principal investigator of the Psyche mission.

The main reason scientists started to doubt the exposed-core explanation is Psyche's relatively low density. The asteroid's dimensions are known from timing observations of stellar occultations and from high-resolution images obtained with the European Southern Observatory's Very Large Telescope in Chile. Meanwhile, studies of Psyche's gravitational influence on the orbits of other, much smaller asteroids, carried out by Finnish astronomer Lauri Siltala, have revealed the object's mass. From the known size and mass, Psyche's mean density turns out to be 3.9g per cubic centimetre – about half the value you would expect for a solid ball of metal.

The density measurements can mean two things. Either Psyche is mainly rock after all, with patches of iron on its surface – the 'lava' plains mentioned before – or the asteroid is a porous rubble pile, in

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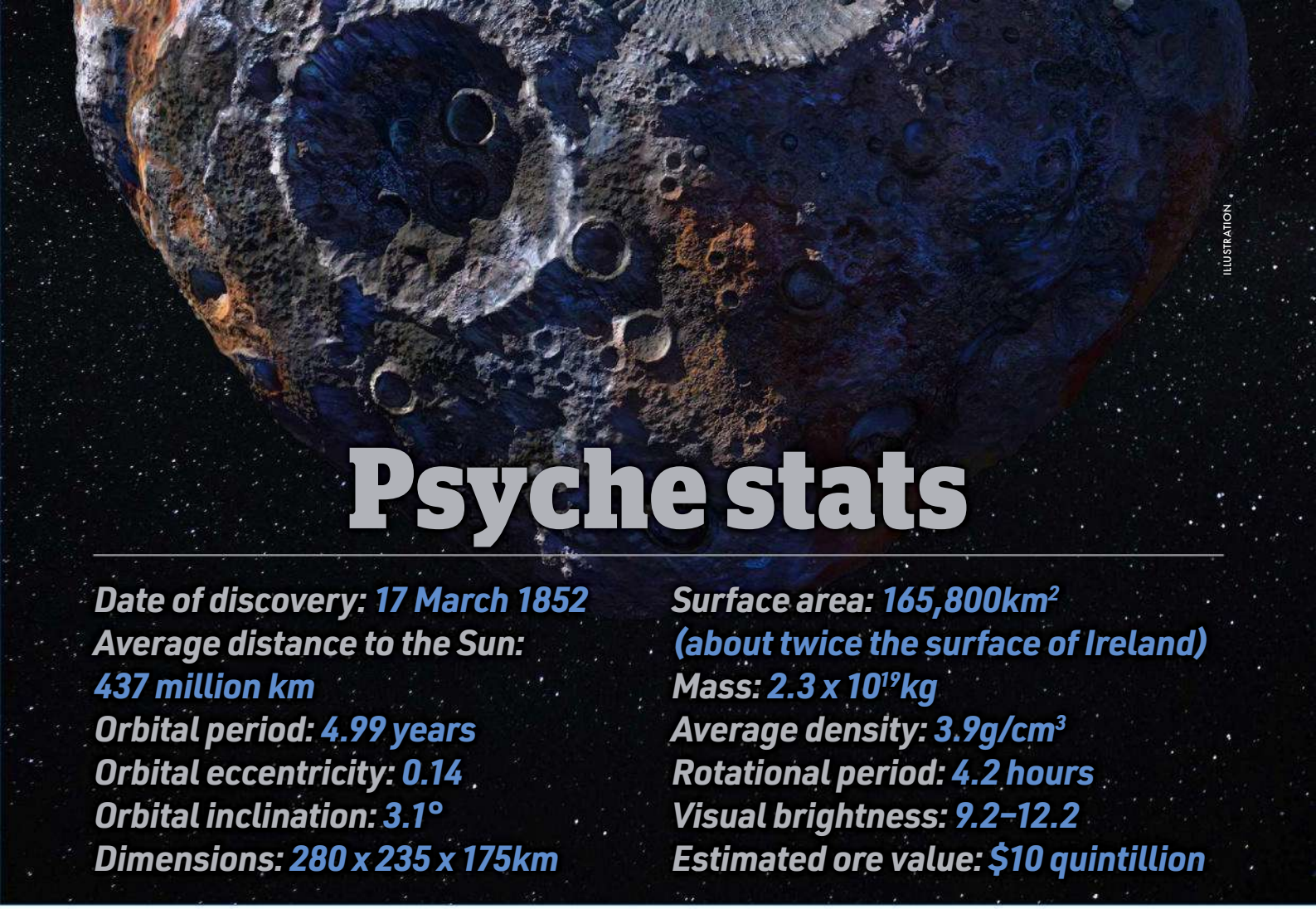


ILLUSTRATION

Psyche stats

Date of discovery: 17 March 1852
Average distance to the Sun: 437 million km
Orbital period: 4.99 years
Orbital eccentricity: 0.14
Orbital inclination: 3.1°
Dimensions: 280 x 235 x 175km
Surface area: 165,800km^2 (about twice the surface of Ireland)
Mass: 2.3 x 10^{19}kg
Average density: 3.9g/cm^3
Rotational period: 4.2 hours
Visual brightness: 9.2–12.2
Estimated ore value: $10 quintillion

which case the iron content could be substantially higher. In 2019, Francis Nimmo and Jacob Abrahams of the University of California Santa Cruz proposed the theory of (ancient) ferro-volcanism – a process you might expect when a newly formed and molten body is cooling down from the outside in. But a team led by David Cantillo of the University of Arizona carried out laboratory experiments indicating that Psyche's spectroscopic properties are best explained by a porous body containing up to 82.5 per cent metal, as they wrote in a 2021 paper.

Then there's the riddle about a possible link with iron meteorites. These are assumed to be fragments of disrupted differentiated bodies – in other words, bodies large enough to have ended up with an iron-nickel core. "The problem is that the asteroid belt shows limited evidence that so many bodies with cores actually disrupted," says Bottke. "This suggests that we are missing something important about Solar System evolution. Our investigation of Psyche may shed light on this mysterious issue."

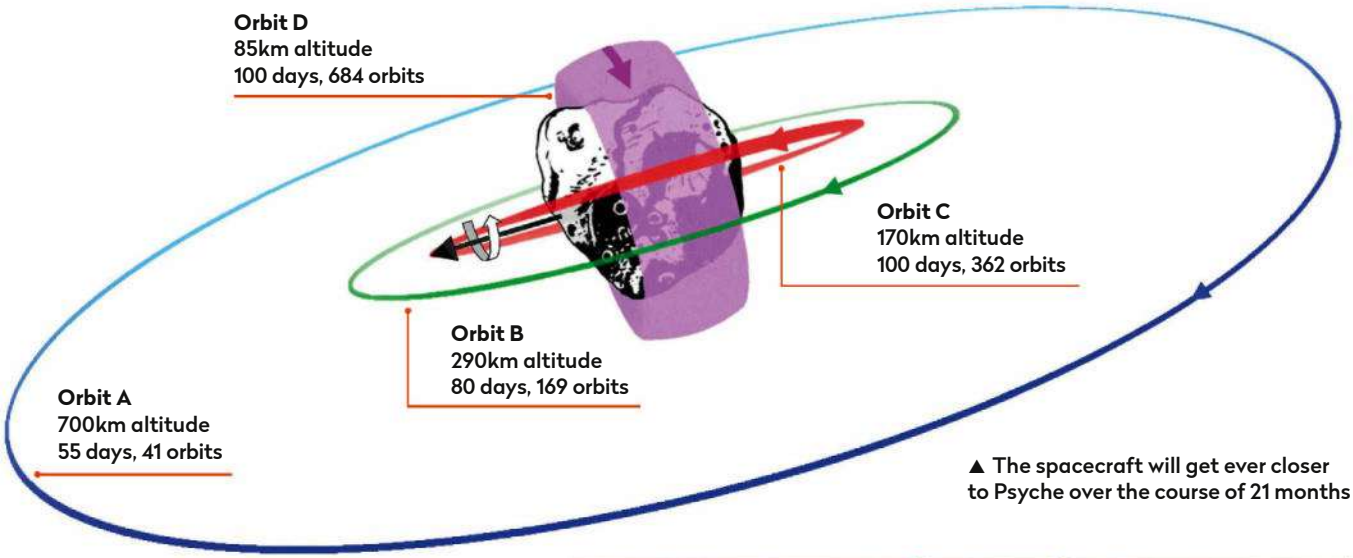
Long road to discovery

Given all of these mysteries, it's not surprising that Solar System researchers look forward to the launch of the Psyche mission on a SpaceX Falcon Heavy rocket from Kennedy Space Center in Florida. First proposed in 2014, Psyche was selected as a finalist in NASA's Discovery programme in 2015 and approved in January 2017 as the 14th entry in this series of focused, cost-effective science missions. A gravity assist fly-by of Mars in 2026, just 500 kilometres above the surface, will give the spacecraft enough energy to reach its target asteroid in the summer of 2029.

Psyche is a roughly cubic spacecraft about the size of a Smart car, built by Maxar Technologies. The mission is led by Arizona State University and will be operated by NASA's Jet Propulsion Laboratory in Pasadena. Two huge arrays of solar panels, with a total span of almost 25 metres and a surface area as large as a tennis court, will provide the power for the science instruments and for the spacecraft's solar electric propulsion thrusters, which are much more versatile than traditional chemical rocket engines.

> *"Psyche will orbit its namesake asteroid at four different altitudes above the enigmatic surface"*

Over a period of 21 months, Psyche will orbit its namesake asteroid at four different altitudes above the enigmatic surface. The first 55-day phase of the mission (orbit A, at 700 kilometres), focuses on general reconnaissance, mapping and magnetic field studies. Next, the craft enters orbit B (290 kilometres), to further study the asteroid's magnetic field and carry out topography measurements for a period of 80 days. Orbit C (170 kilometres, 100 days) will mainly be used to precisely map the asteroid's gravitational field, providing information about ▶



▲ The spacecraft will get ever closer to Psyche over the course of 21 months

▶ its interior structure. Finally, Psyche will lower itself to an altitude of a mere 85 kilometres (orbit D, also 100 days) to determine the chemical composition of the asteroid's surface.

Up close and personal

The mission's multi-spectral imager – basically two identical cameras with a suite of filters – is going to provide high-resolution images of Psyche's surface, and will certainly make the NASA artists' impressions obsolete, although everyone is curious about how realistic they will turn out to have been. A 2-metre boom carries a set of magnetometers, as well as a gamma-ray and neutron spectrometer, which will measure the abundances of various chemical elements on the asteroid's surface. Precise timing of the radio communication with the spacecraft – through its 2-metre-diameter antenna – enables mapping of Psyche's gravitational field.

Apart from its main science payload, with a total mass of just 30kg, the Psyche mission is also unprecedented in that it is tasked with testing a new method of spacecraft communication, using near-infrared lasers instead of radio waves. Known as Deep Space Optical Communications (DSOC), this technology demonstration project promises to achieve a substantially higher data rate. The laser signals from the craft will be collected by

▲ NASA engineers work on Psyche's innovative solar electric propulsion thrusters

NASA/JPL-CALTECH X 2, STOCKTREK IMAGES/ISTOCK/GETTY IMAGES, MEL STOUTSENBERGER/ALAMY STOCK PHOTO, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 2

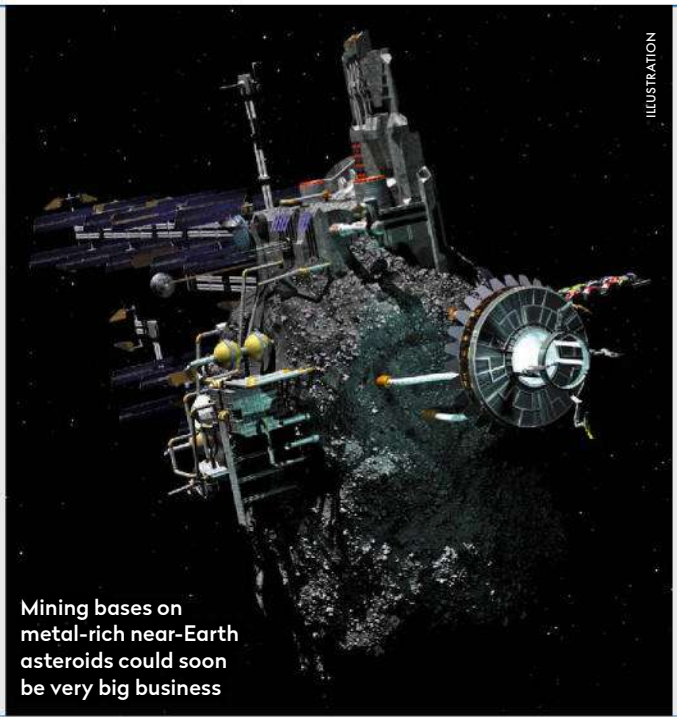
A cosmic colliery?

Some argue that asteroids like Psyche could be mined for their valuable metals

Metal-rich asteroids like Psyche are scientifically interesting, but they may also have large economic value. According to some estimates, Psyche could well contain a staggering 10 quintillion dollars' worth of iron, nickel and other precious metals. But even if this were true, would humans actually be able to extract such metals and return them to Earth?

"The potential of asteroid mining has made entrepreneurs excited around the world," says Bill Bottke (Southwest Research Institute). But, he adds, "asteroid mining is hard and Psyche is far away. It may be a long time before the world suggested by *The Expanse* TV show becomes a reality. When that day arrives, though, Psyche would make an excellent target, depending on what we want to do with its metals."

Other M-type asteroids, like the near-Earth objects 1986 DA and 2016 ED85, are much smaller but also much easier (and less costly) to exploit. Small-scale asteroid mining may well become a reality before the end of this century.



ILLUSTRATION

Mining bases on metal-rich near-Earth asteroids could soon be very big business

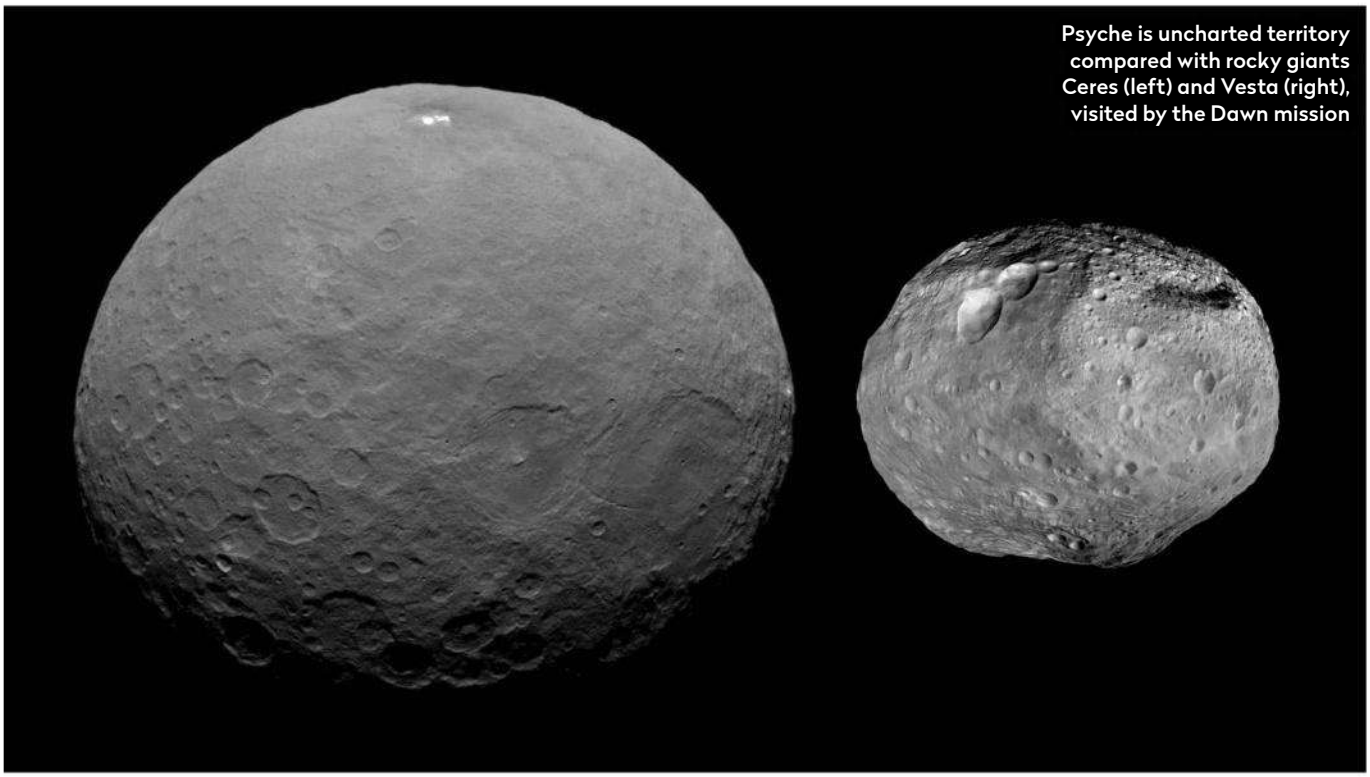
▲ **The 200-inch (5-metre) Hale Telescope will receive the craft's communications via laser**

the venerable 5-metre Hale Telescope at Palomar Mountain in California. Engineers expect to use this form of laser communication more often in future missions to Mars.

Psyche is a vitally important mission in the exploration of our Solar System, and is more or less comparable to NASA's Dawn mission, which orbited the two largest main belt asteroids Ceres and Vesta between 2011 and 2018. "But this mission differs from Dawn in the sense that Psyche is a different kind of object than has been visited thus far," says Bottke. While Psyche (like Ceres and Vesta) is likely to be a primordial object, Bottke emphasises that very little is known about the metal-rich asteroid with much certainty. "For example," he says, "it is still an open question whether Psyche formed in the inner or outer Solar System, or whether any of our known meteorites are a good match to its surface."

Scientists are likely to have a lot of answers within a few years. But then again, Psyche may also provide them with new questions and unexpected results. "Secretly, I am hoping that Psyche is something really strange," says principal investigator Elkins-Tanton. "Not a core, not a recognisable kind of unmelted meteoritic material. Maybe it's a metal-rich remnant of the material that was near the Sun in the earliest history of the Solar System. My secret hope is to be really surprised!"

Govert Schilling's book *The Elephant in the Universe* is published by Harvard University Press



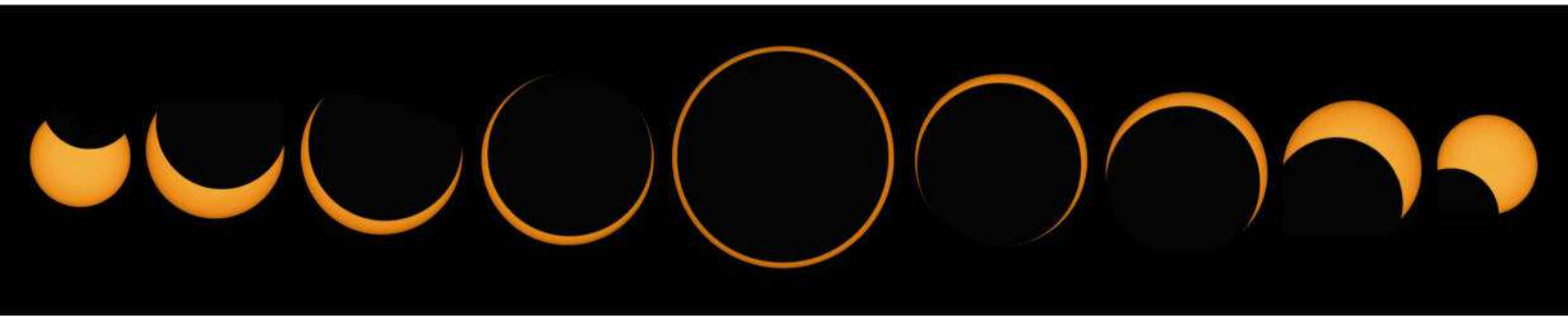
Psyche is uncharted territory compared with rocky giants Ceres (left) and Vesta (right), visited by the Dawn mission

The fundamentals of astronomy for beginners

EXPLAINER

What makes a 'ring of fire' eclipse

Jamie Carter explores the mechanics behind annular eclipses



▲ **The different phases of an annular 'ring of fire' eclipse as the Moon passes across the Sun**

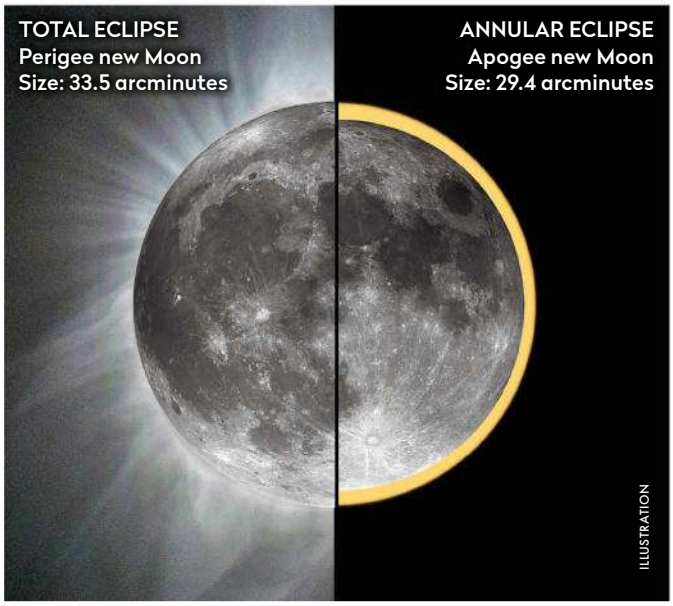
The mere mention of a solar eclipse may conjure thoughts of totality and a glimpse of the Sun's ghostly corona, the outermost part of its atmosphere, as day turns to night. These are two effects of a total solar eclipse, but what will take place across the US in October is a different kind: an annular solar eclipse. Although the corona remains out of sight and daylight persists during these eclipses, they have other spectacular features, notably the 'ring of fire'.

That's what will be visible on 14 October 2023 when people across the southwestern US, and Central and South America will see a thin, burning 'ring' around the Moon for over four minutes, as 90 per cent of the Sun is blocked. Remarkably, the remaining 10 per cent of the Sun's face that remains visible around its perimeter is enough for daylight to persist, and to mean that this eclipse can only be safely viewed through eclipse glasses or solar filters.

So what exactly is going on when annular eclipses occur, and why do they differ from total solar eclipses?

Well, an annular solar eclipse happens when the Moon appears smaller than the Sun as it crosses its disc, and so doesn't block out all of its light. This happens because the Moon's orbit around Earth is not a perfect circle but a slight ellipse shape. There's a point in the Moon's orbit when it's nearest Earth, perigee, and appears big enough to block the Sun's disc, and a point when it's farthest away, apogee, and doesn't appear to cover the Sun. The distance from the Moon to the centre of Earth changes from a maximum of around 406,000km at apogee to around 357,000km at perigee.

Whether there will actually be an eclipse in any given orbit of the Moon around Earth depends on whether the new Moon crosses the ecliptic – the apparent path of the Sun across the sky. When an eclipse does occur during a perigee new Moon, it creates a cone-shaped umbral shadow in space, and where the tip of this shadow touches Earth's surface we see a total solar eclipse.



▲ **The comparative sizes of perigee (nearest) and apogee (farthest away) Moons, and the two different types of eclipses they create**

The ring cycle

During the maximum phase of a total eclipse, along a narrow path of totality it's possible to experience darkness in the day, as all of the Sun is obscured. But when an eclipse happens at an apogee new Moon it's not possible to witness totality anywhere: the dark 'umbral' shadow cast by the Moon isn't long enough to reach Earth. This, means observers along the path of annularity see a 'ring of fire'.

What happens before and after maximum eclipse is very similar for both eclipses. For around 80 minutes or more

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The four kinds of solar eclipse

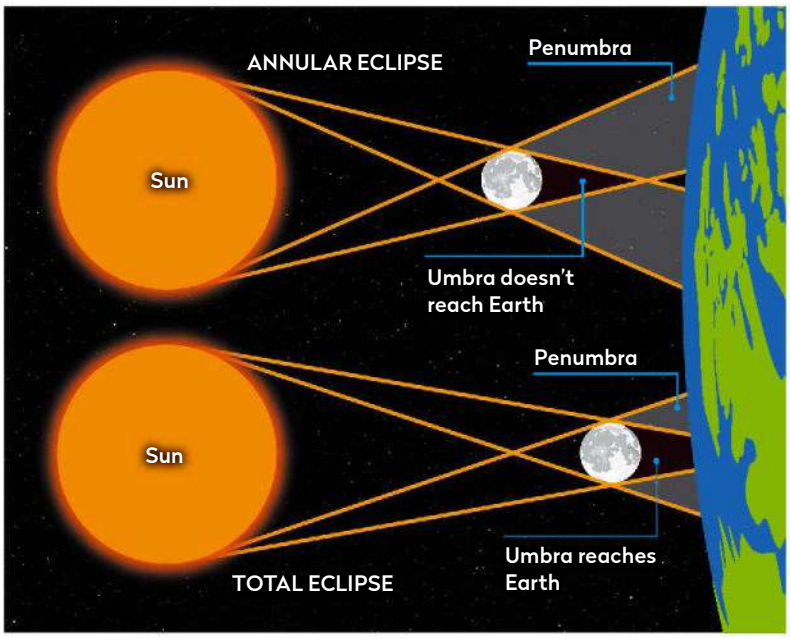
Eclipses are shaped by the Moon's distance from Earth and by the Sun–Moon–Earth alignment

Partial solar eclipse
A new Moon moves across part of the Sun's disc over a few hours. How much of the Sun is blocked depends on where the observer is, but the Sun is only ever partially obscured, wherever you are.

Total solar eclipse
The alignment is perfect and 100 per cent of the Sun's disc is blocked for up to seven minutes. Within a narrow path of totality, the Sun's wispy corona can be viewed with the naked eye.

Annular solar eclipse
The Moon's dark umbral shadow doesn't reach Earth. For those along the path of annularity, a 'ring of fire' can be viewed (through eclipse glasses or solar filters) for up to 12 minutes.

Hybrid solar eclipse
Often called an annular-total solar eclipse, this is the rarest type. It begins and ends as an annular, but Earth's curvature causes a short totality in the middle of the eclipse path.



▲ **Annular eclipses occur when the Moon is further away from Earth; when the Moon is closer to Earth and so appears larger, a total eclipse can occur**

either side of totality or annularity, there's a partial solar eclipse. The new Moon approaches to take an increasingly larger bite out of the Sun, before moving away. The difference is the few minutes in the middle.

Just as with a total eclipse, during an annular solar eclipse it makes a difference where you stand within the central path of annularity. Along the centre line, the 'ring of fire' lasts the longest – up to 12 minutes – but this decreases to just a second on the northern or southern edges of the path.

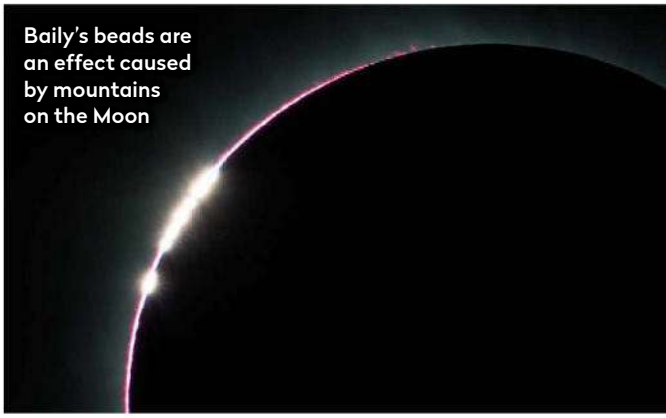
Those at the edge of the path may seem disadvantaged, but there's a reason why some eclipse-chasers gather there. Although a perfect 'ring of fire' is only momentarily visible, from these positions it's possible to see Baily's beads – spots of sunlight pouring through lunar mountains and valleys. They flare for a few seconds and cause a 'broken ring'.

On 14 October 2023, the path of annularity will begin on land over Oregon and sweep across California, Nevada, Utah, Colorado, Arizona, New Mexico and Texas, crossing several US National Parks and International Dark Sky Parks. The 'ring of fire' will also be visible from Mexico, Belize, Honduras, Nicaragua, Panama, Colombia and Brazil.

The next annular solar eclipse will occur on 2 October 2024 in the Pacific Ocean. Perhaps the best place to witness annularity will be amid the carved human moai figures on Rapa Nui (Easter Island). It will also be visible shortly before sunset from Patagonia in southern Chile and Argentina.

Eclipses are spectacular sights, yet it's remarkable that we exist at a time when the Moon and Sun can be exactly the same apparent size in the sky to make total solar eclipses possible. Because the Moon is slowly drifting away from Earth at a rate of 4cm per year, there will come a time when it will no longer appear big enough to cover the whole Sun. In about 563 million years, every solar eclipse will be annular.

Jamie Carter is the editor of **whenisthenexteclipse.com** and an eclipse-chaser for life



Baily's beads are an effect caused by mountains on the Moon

Keep your camera sensor clean

Dust and debris make for grainy, blurry shots – here's how to keep your DSLR free of them

◀ **If you're manually cleaning your DSLR, use only specialist products that are designed for the job**

Astrophotography can be quite unforgiving, exposing our cameras to conditions that push their design capabilities. One big issue is dirt, often in the form of dust, which builds up on the sensor from all those long nights outside in the elements. Cameras used for daytime landscape, portrait or traditional forms of photography spend their lives with camera lenses firmly secured to the front of the body, theoretically sealing the dust and general dirt out. Exposure times are usually fractions of a second too, which exposes the camera sensor to the air for relatively short periods of time.

In astrophotography, however, our cameras are often attached to a telescope via a T-ring adaptor. This system is not sealed and so will allow dust to creep in, especially as our kit is outside for hours at a time. The exposure times we need to capture faint, nebulous deep-sky objects are considerably longer too, exposing the camera sensor to the air for 30 seconds or more at each exposure. All these factors combined allow dust, dirt and other debris to accumulate on the sensor over time.

This build-up often goes unnoticed, as small amounts don't affect image quality, but sometimes a larger, more noticeable piece of dust or a smudge will appear on our images. Identifying where the dust is within our imaging system is often a case of looking at the shape and size of the mark. Dust on the front lens of a refractor will appear as a large disc in your images, or as a dark 'doughnut' if using a reflector or Cassegrain-style telescope.

Dust on the sensor will appear as small, solid black marks or small discs. These can often be removed by using the 'spot healing' brush or similar in post-processing software, but become problematic when, as is often the case, they're in key areas of the object we are imaging. Only at this stage would we recommend cleaning our camera sensors.

Chris Grimmer is an experienced astrophotographer and photographer specialising in infrared images

Going under the hood

Most, if not all, modern DSLR cameras have an automatic cleaning routine within their settings. This routine applies ultrasonic vibrations through the protective filter that covers the sensor, which in most instances will dislodge the dust. On most models, these routines can be set to run each time the camera is switched on, or be triggered manually via the settings as and when needed.

In those instances where the dust or dirt proves more stubborn, there are options for us to manually clean the sensor. When we talk about cleaning the sensor, what we're actually cleaning is the filter that sits in front. In modern DSLRs there are a pair of filters: an infrared/red-suppression filter sits closest to the sensor, and above that is a clear (or infrared block) filter, which is where the dust often collects. The filters form a seal over the sensor, so no dust should ever get behind them; if you find that the dust has got in there, then we advise enlisting professional help to remedy it.

What you'll need

▶ A balloon air blower, one of the simplest ways to try to remove fluff, dust or stray hairs

▶ A cleaning brush. These can be a traditional brush or a plastic spatula covered in a soft fabric that attracts and holds the dust

▶ A cleaning pen. Available from most camera shops, these often include a soft brush on one end and a cleaning pad on the other

▶ Cleaning fluid for applying with a lint-free cloth

ALL PICTURES: CHRIS GRIMMER

Step by step

Step 1

Modern DSLRs include an auto cleaning routine. The settings will be make- and model-dependent. For our Canon 6D, this is located under the 'Sensor cleaning' sub-menu. The cleaning routine can be set to occur every time the camera is turned on.

Step 2

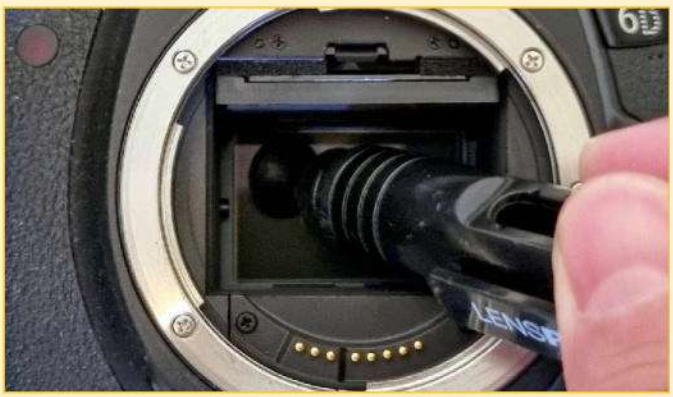
If electronic cleaning is unsuccessful, try to blow the dust or debris away. First, in your cleaning settings, look for an option to 'Manually clean' (or similar). This flips and locks the mirror up and holds the shutter open, exposing the filter/sensor below.

Step 3

Holding the camera with the sensor pointing downwards, squeeze the air blower to gently puff air across the sensor. Repeat this several times and then turn off the camera, which will close the shutter and reset the mirror to its correct position.

Step 4

For stubborn issues, specialist camera-cleaning brushes and wipes are available. As before, set your camera to manually clean to take the mirror and shutter out of the way. Being sure to keep the camera pointing downwards, brush gently across the sensor.



Step 5

For the most stubborn of marks, a cleaning pen can be used. Follow the previous instructions to open the shutter and then, with the camera facing downwards, gently rub the tip of the cleaning pen across the sensor or per your pen's instructions.

Step 6

The final option open to us is using a dedicated sensor/filter cleaning fluid. Added to a lint-free cloth, this can be used to gently rub across the sensor, hopefully removing any remaining marks. Take great care not to scratch the sensor filter.

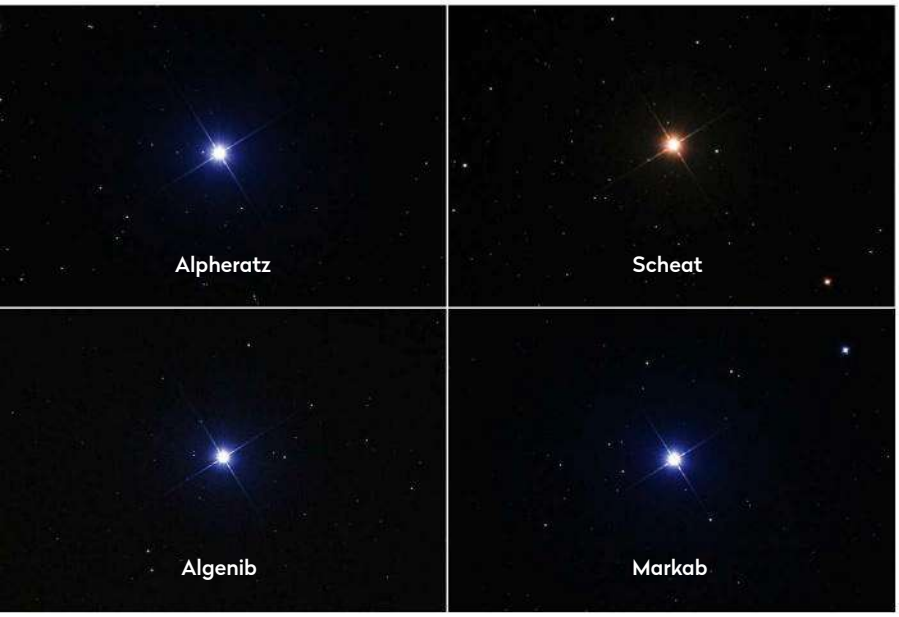
Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY

CAPTURE

Make a colourful star library

Compile your star photos by spectral type to create a spectacular display



▲ **Build your own reference library to showcase the colour differences between stars, as shown here with the four corner stars in the Great Square of Pegasus**

ALL PICTURES: PETE LAWRENCE

How many times have you seen a star described as 'red' appearing slightly orange, or called 'blue' but looking white? By building a library of star photos you'll be able to see their subtle colour variations. A large library will create a very impressive display and will spectacularly show just how different star colours can be.

Photographing stars isn't hard, but capturing their colour is a bit more challenging. A star is a point source of light, which normally photographs as an over-exposed white dot. In addition, Earth's atmosphere wobbles the star's light due to micro-refraction, causing it to 'paint' over a larger area. The worse the seeing, the larger the star's dot becomes in your photos. The colour is there, but forced to a region that isn't over-exposed. This is on the very edge of the star's image. Examine a star image up close and you'll see the colour preserved in a narrow, few-pixels-thick ring around the bright inner 'white' over-exposed core.

There are various tricks to make this colour more obvious. Star trails do it beautifully as, with the correct settings, stars don't over-expose and their colour is simply smeared into a line. Another involves de-focusing the image, causing the star's light to expand into a blurry disc that contains a spread of the star's colour. Another is shooting in haze or fog, when starlight scatters into a disc which can be photographed for a record of the star's colour.

You can re-introduce colour in post-processing too. Select the outer colour rings of stars, isolate this and blur it into an artificially larger area which can then be carefully re-introduced into some of the over-exposed star disc as a colour wash. It does take a bit of skill to make this look natural.

However you do it, capturing a star's colour lends itself nicely to comparison purposes. There is literally a whole spectrum of colours to choose from, with the exception of green (stars that peak at green wavelengths are swamped by the adjacent spectral colours and don't look green as a result).

There are several stellar colour classification methods, the modern one being the Morgan–Keenan (MK) system. This ranks stars from blue to red, the main categories identified by the letters O, B, A, F, G, K and M. These are broken down into 10 sub-divisions represented by a number suffix: for example O4, B0, B1, A3 or K5. Our Sun's colour classification is G2. The categories and sub-categories are ordered by hottest O0 through to coolest M9, determined by using one of the many digital sky apps.

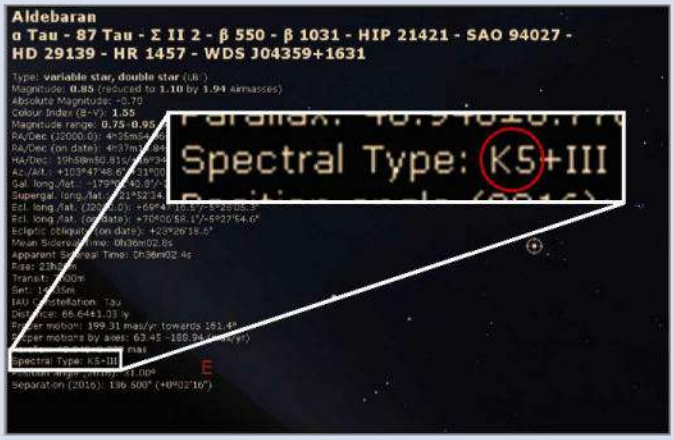
Armed with this information, see how many star colour variants you can identify, capture and present. A large number of examples displayed side by side will finally show once and for all why that orange-looking star is described as red! Good luck with gathering your collection.

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: DSLR or equivalent, telephoto lens or telescope, driven equatorial mount (optional)

✉ **Send your images to:**
gallery@skyatnightmagazine.com

Step by step

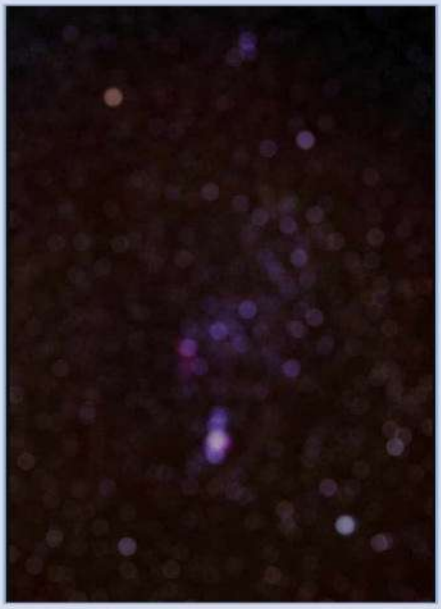


STEP 1

Selecting a target star is relatively easy thanks to apps such as Cartes du Ciel or Stellarium. Look for 'spectral type'; it's the letter plus its following number that you require. It will take a bit of research to locate examples in every category, the internet being a good place to look for examples if you're stuck.

STEP 2

Decide how you're going to capture your star to best reveal its colour, or consider using several methods together. For the best star trails, set a relatively low ISO, say 400–800, with aperture fully open then closed by several stops. Try a 5-minute exposure to test and adjust (final settings will depend on your setup).



STEP 3

For the defocused method, we'd suggest using a tracking mount for the best results. Focus on the target star as accurately as possible, then defocus slightly until the star appears as a disc. As you do this, the surface brightness of the disc will decrease. Aim for a low ISO to maintain tonal quality. Experiment with settings to achieve the best result.

STEP 4

Atmospheric halos are produced naturally and are best seen around brighter stars when conditions are foggy or at least quite misty. These conditions are difficult to predict, but it's always worth staying alert. Maintain focus and take an exposure that reveals the star disc clearly. A tracking mount is recommended.

Class	Star	Trail	Defocused	Normal
O9.5	*Mintaka (δ ORI)*			
B5	*Aludra (η CMa)*			
A5	*Rasalhague (α OPH)*			
F5	*Procyon (α CMi)*			
G2	*Sadalmelik (α AQR)*			
K5	*Eltanin (γ DRA)*			
M0	*Mirach (β AND)*			

STEP 5

Create a table in which you can place your results. You can start easy by selecting a star from each spectral class, near the middle if possible. As time goes on, you can always swap these out for better examples if you find any. You may encounter delays if a specific star is only visible at a certain time of year.

Class	Star	Trail	Defocused	Normal
O9.5	*Mintaka (δ ORI)*			
B5	*Aludra (η CMa)*			
A5	*Rasalhague (α OPH)*			
F5	*Procyon (α CMi)*			
G2	*Sadalmelik (α AQR)*			
K5	*Eltanin (γ DRA)*			
M0	*Mirach (β AND)*			

STEP 6

You can take your time over filling the table, swapping in better candidates if they arise. If you complete the basic class table, you could expand the project by adding additional sub-categories for each main class. You could, for example, choose a 0, 5 and 9 candidate or, if you're feeling brave, subdivide into all 10.

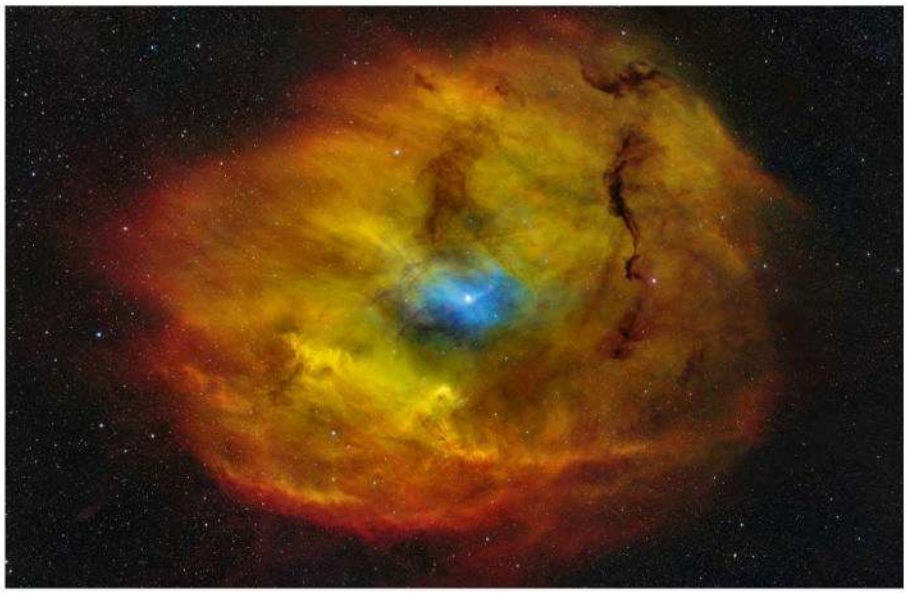
Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Maximising large, faint nebulae

How to draw out detail in big, low-surface-brightness objects

Astronomy Photographer of the Year
Advice from a 2022 shortlisted entrant in the 'Stars and Nebulae' category



◀ Mathew explains how he reprocessed his shortlisted image, The Runaway Star of Sh2-27

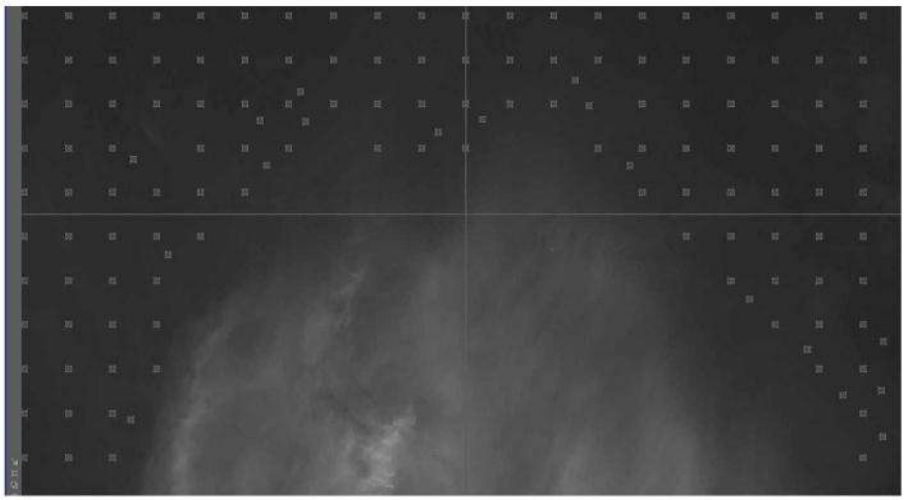
One of the enjoyable aspects of astrophotography is exploring new techniques to improve your processing skills. Since originally processing my narrowband image, 'The Runaway Star of Sh2-27', shortlisted in 2022's APY competition, my processing today is quite different.

Sh2-27 is an extremely large ionisation nebula in Ophiuchus, which spans 13 degrees or 26 full Moons across the sky. I imaged it with a Nikon 200mm f/2 lens and a full-frame ZWO ASI6200MM camera, and even with the very large field of view with this setup, I still needed a three-panel mosaic to capture it all!

First, I needed to remove any unwanted gradients from light pollution, moonlight and sky glow. After using the WBPP script in PixInsight to perform image calibration and registration, I utilised the Normalize Scale Gradient (NSG) script by John Murphy. This script corrects the brightness and gradients of your subs using differential photometry to model the relative scales and gradients.

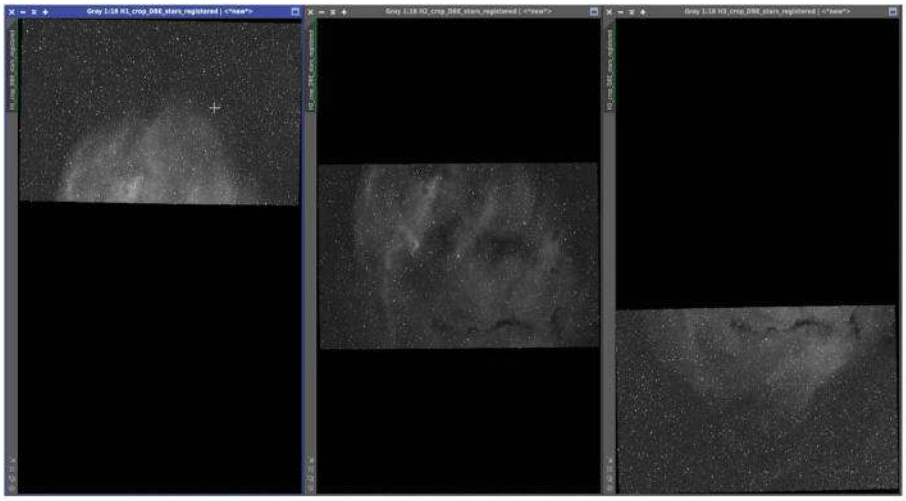
I image at a dark site but I still find NSG very useful as a first step. I then looked at doing a second sky subtraction on the master images, using the Dynamic Background Extraction (DBE) tool in PixInsight. For images with complex emission structures and unwanted gradients it's especially useful to perform the DBE on a starless linear image. I use StarXterminator on the linear master and set this to also generate a separate star image with unscreened stars.

With the starless linear master, you can then place many DBE samples using a high pixel-rejection tolerance; you can easily see and avoid placing samples in areas of true emission signal. The background model can be subtracted

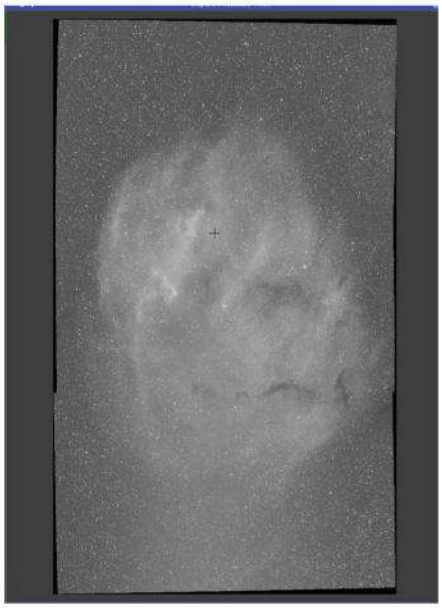


▲ Dynamic Background Extraction (DBE) sample points on a starless master image, avoiding Sh2-27's nebulosity. Mathew used a pixel-rejection tolerance of 0.9 for this process

ALL PICTURES: MATHEW LUDGATE



▲ **The three panels registered using the MosaicbyCoordinates script in PixInsight**



▲ **Initial Ha combined mosaic using the PhotometricMosaic script**

with 'Normalize' selected and the star image can be added back to the DBE corrected image using the PixelMath expression: ~((~starless DBE)*(~stars)).

Assemble the mosaic

The next step is to combine the mosaic panels. I used the PhotometricMosaic script in PixInsight, which gives excellent results, with seamless blends between panels. To use it, you must first plate-solve all your mosaic panel images and then run the MosaicbyCoordinates script. Once the registered panels are created, I trimmed ~2 pixels from each edge using TrimMosaicTile and then ran PhotometricMosaic. I find the defaults tend to work well, but it's worth trying different combination modes to see which blends the panels most seamlessly.

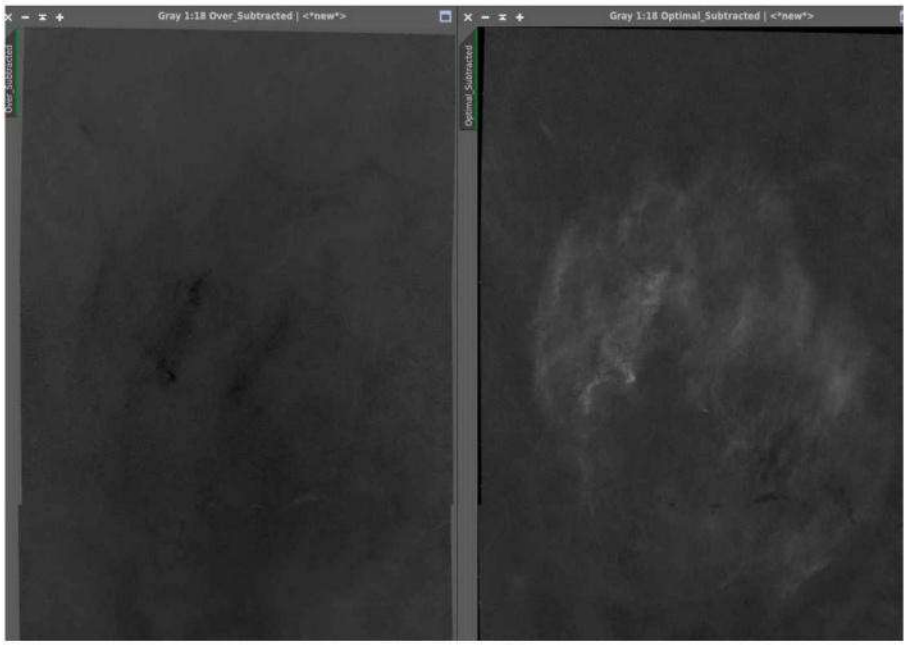
Lastly I performed continuum subtraction on my narrowband master images. While narrowband filters block most unwanted wavelengths, a small amount of the continuum light is allowed through, masking faint emission structures. In amateur astronomy, we usually don't have specific off-band filters, but we can use broadband filters for a similar effect. For example, for Ha we would subtract the broadband red continuum to reveal the pure Ha emission. I usually do continuum subtraction using PixelMath in PixInsight, running the equation: Narrowband - (Broadband-median(Broadband)) * scaling factor.

As the broadband filter is much wider than the narrowband filter, a scaling factor must be used to avoid under- or over-subtracting the continuum from the emission signal. I usually determine this scaling factor through trial and error.

While continuum subtraction is usually done on master images containing stars, this does create artefacts where the stars are under- or over-subtracted, and these artefacts need to be repaired using different masking techniques. If the image is being produced for aesthetic aims, then you can often get an acceptable result with much less work, by performing the continuum subtraction on starless images using your star-removal tool of choice.

Finally, once the narrowband SHO master images have been created, these are taken into Photoshop as layers to create the final colour image.

Mathew Ludgate is a New Zealand astronomer fascinated with capturing the southern sky



▲ **Left: over-subtracted image, with little signal due to too large a scaling factor. Right: a subtracted image using a more appropriate scaling factor, determined by trial and error**

3 QUICK TIPS

1. When combining mosaic panels, take care to avoid uneven gradients between the combined panels.

2. Check overlapping areas of your mosaic panels carefully for any star artefacts. Try adjusting the size of the overlap and the combination mode to see if these can be avoided.

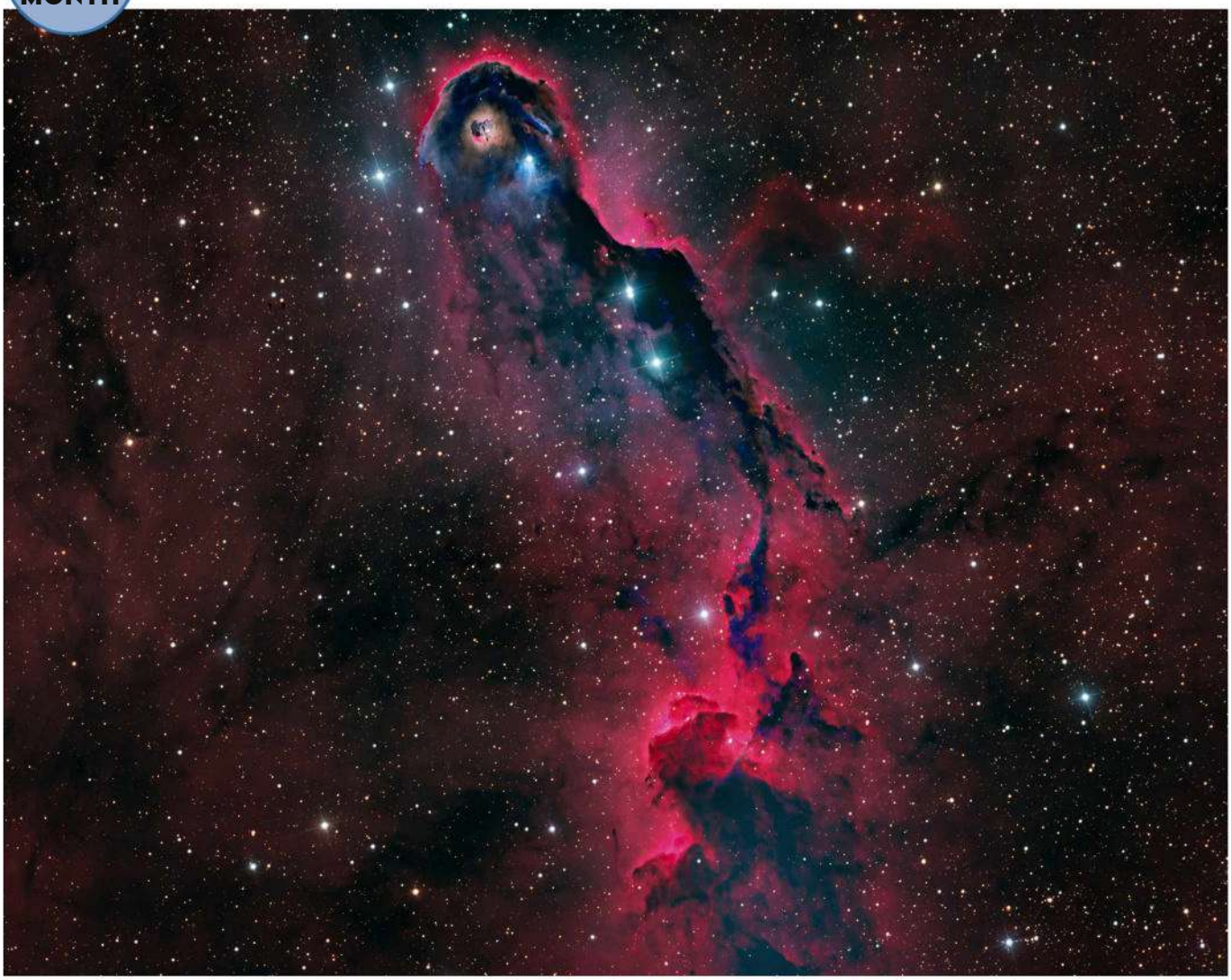
3. If you perform continuum subtraction on starless images, also create a continuum subtracted image with stars, then compare them to check for any introduced artefacts.

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More ONLINE
A gallery containing these and more of your images

PHOTO OF THE MONTH



△ The Elephant's Trunk Nebula

Vikas Chander, Animas, New Mexico, USA, 15–23 July 2023

Vikas says: "I started out fascinated by the colours of the Hubble palette and narrowband imaging, but now find myself leaning more towards the RGB and broadband colour palette, thanks to images like this one!"

Equipment: FLI ProLine PL16803 camera, PlaneWave CDK17 f/6.8 astrograph, Software Bisque Paramount ME mount
Exposure: L 27x 1,200", R 16x 900", G 16x 900", B 16x 900", SII 18x 1,800", Ha 18x 1,800", OIII 18x 1,800"
Software: PixInsight, Photoshop, Voyager

Vikas's top tips: "My recommendation to someone starting out is not to buy any equipment yet, but rather join a community such as AstroBin or one of the many online astrophotography groups. Learn about the night sky and the different types of deep-sky objects. Then join a remote observatory and log on to one of their scopes to image your favourite targets. For less than $20/hour you can use some of the best equipment in the world, under the best skies."

△ Jupiter and Ganymede

Ivana Peranic, Brighton, 15 December 2022

Ivana says: "I took this during a rare night of good seeing on the south coast. I planned to image Jupiter and the transit of Ganymede. I was excited to see I'd managed to resolve a sliver of detail on Ganymede as well! It had just begun its transit so was still well defined, and the Great Red Spot had just started appearing."

Equipment: ZWO ASI1662MC camera, Celestron CPC 800 Schmidt-Cassegrain
Exposure: 2.29/1,000", gain 440
Software: SharpCap, AutoStakkert!, RegiStax, GIMP

△ The Pleiades

Ronald Brecher, Guelph, Ontario, Canada, 6 December 2020–9 February 2021

Ronald says: "The weather didn't cooperate, so it took over two months to capture, often just 15 minutes at a time. It's my favourite M45 so far."

Equipment: QHY 367C Pro camera, Takahashi FSQ-106EDX4 refractor, Paramount MX mount
Exposure: 123x 5', 10h 15' total
Software: PixInsight

▽ Sunspot 3363

Anton Matthews, Bristol, 17 July 2023

Anton says: "I'm happy with the results, but I plan on using a DayStar focal reducer to obtain a larger area of the disc, thereby capturing surrounding details as well."

Equipment: ZWO ASI178MM camera, Sky-Watcher Evostar 80ED DS-Pro refractor, Sky-Watcher AZ-GTiX mount
Exposure: Best 200 of 1,000 frames
Software: AutoStakkert!, ImPPG, GIMP

△ Barnard 312

Pro Giacomo, Torricella, Italy, 11–13 July 2023

Pro says: "Dark nebulae are among the coldest objects known in astrophysics, with internal temperatures in the order of 10K. Mainly composed of molecular hydrogen and helium, they're difficult to observe at such low temperatures."

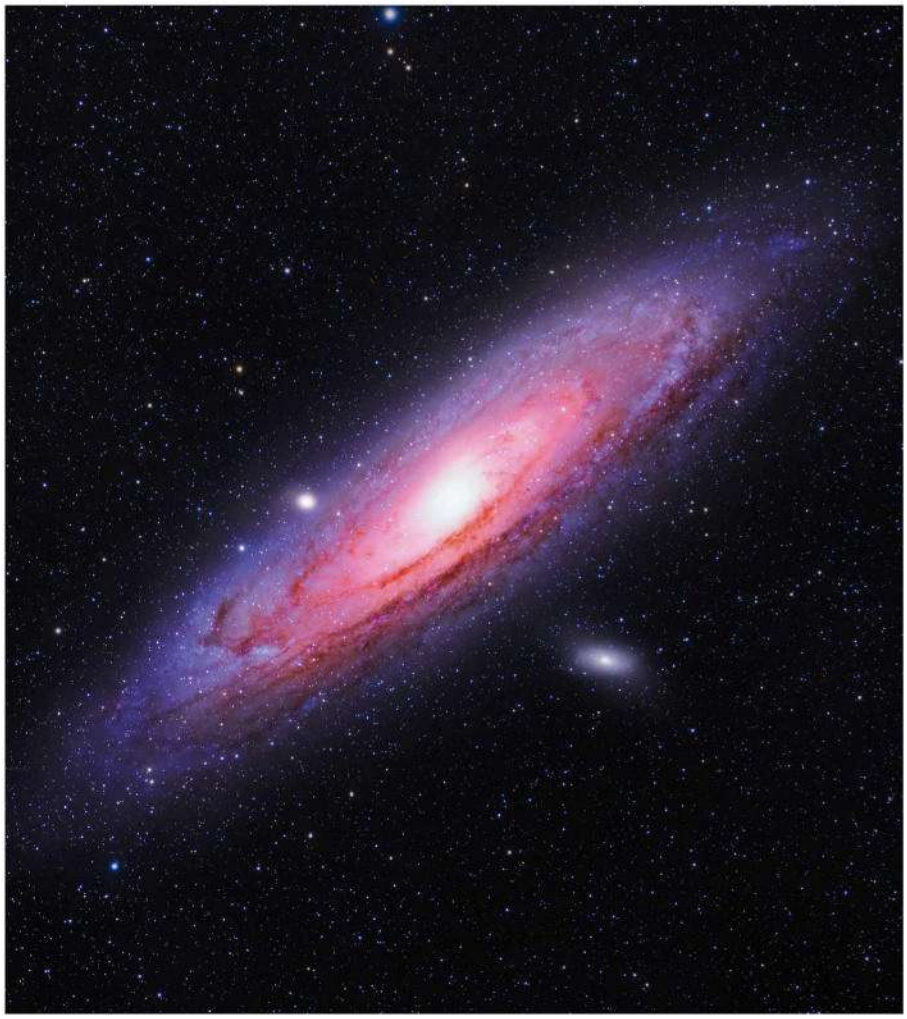
Equipment: ZWO ASI294MC-Pro camera, SharpStar 94EDPH refractor, Sky-Watcher EQ6-R Pro mount **Exposure:** 90x 300" **Software:** PixInsight, Photoshop

M31, the Andromeda Galaxy ▷

Harshwardhan Pathak, IC Astronomy Observatory, Spain, remotely via Telescope Live, 15 July 2023

Harshwardhan says: "The biggest challenge is in the processing: first I need to care about the core, which can get blown out, and secondly about the colours in the arms of the galaxy."

Equipment: QHY600PH-M camera, Takahashi FSQ-106EDX4 astrograph, Paramout MIX+ mount **Exposure:** L 15x 300", R 15x 300", G 15x 300", B 15x 300" **Software:** PixInsight, Photoshop



Sturgeon Moon ▷

Dario Giannobile, Cefalà Diana, Sicily, Italy, 1 August 2023

Dario says: "The castle of Cefalà Diana seemed like the perfect place to capture August's supermoon, though I had to walk 2.6km and set my tripod up in the middle of a field to get the right angle!"

Equipment: Canon EOS 7D DSLR camera **Exposure:** landscape ISO 100 f/8, 1–2"; Moon ISO 800 f/6.3, 1/60" **Software:** Photoshop

◁ Fireball meteor

Michael Kleinburger, Hochkar, Austria, 15 July 2023

Michael says: "This is a once-in-a-lifetime photo. I was there to take Milky Way photos, but was astonished to see this huge fireball heading south across the sky. It was visible for almost a minute in all its colourful glory."

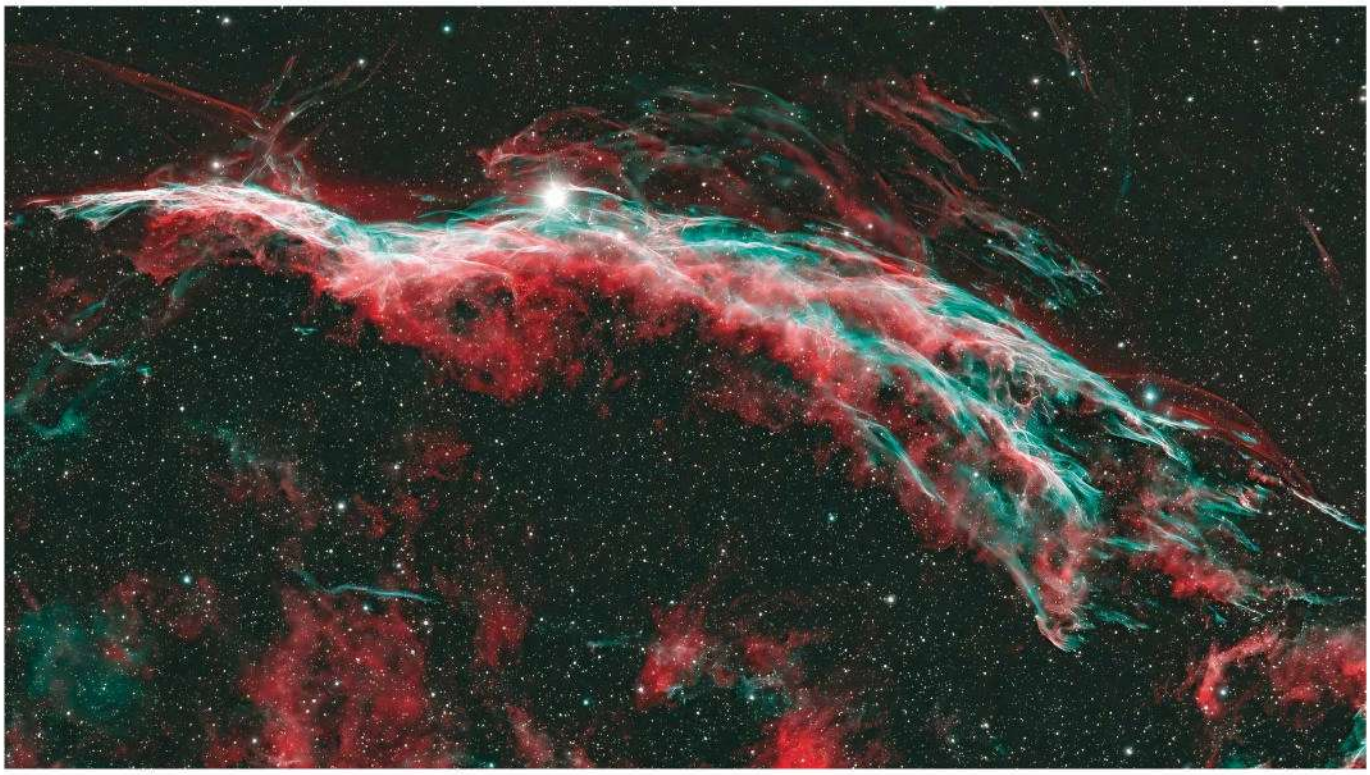
Equipment: Nikon Z6 mirrorless camera, Nikon Z 50mm lens **Exposure:** ISO 400 f/2.8, 60" **Software:** PTGui, Photoshop

▽ The Western Veil Nebula

Jonathon Elliott, Gloucester, 16 July 2023

Jonathon says: "The skies in the UK have not been kind lately, but I managed to capture five hours of data on the Witch's Broom or Western Veil Nebula."

Equipment: ZWO ASI2600MM Pro camera, SharpStar 140PH f/6.5 refractor, Sky-Watcher EQ6-R Pro mount **Exposure:** Ha 5', OIII 5' **Software:** PixInsight



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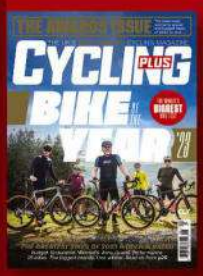

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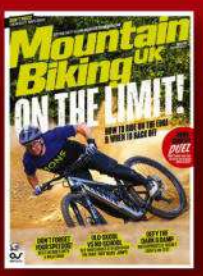

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86
Apx26 camera on test: could Atik's mono marvel get you imaging like a pro?

PLUS: new books on space sci-fi, Einstein, light pollution and more, plus a roundup of the latest astro gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

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Our experts review the latest kit

FIRST LIGHT

Atik Apx26 mono camera

For a premium pricetag, this cooled CMOS delivers proper pro performance

WORDS: TIM JARDINE

VITAL STATS

- **Price** £5,379
- **Sensor** Sony IMX571
- **Resolution** 6,244 x 4,168
- **Exposure range** 1ms–24h
- **Connectivity** USB 3.0
- **Size** 152mm x 89mm
- **Weight** 1kg
- **Supplier** See Atik Cameras website for approved dealers
- **www.atik-cameras.com**

UK-based Atik Cameras recently added a 16-bit astrophotography camera to its offering, in the shape of the Apx26. It's a 26-megapixel CMOS camera available in both mono and one-shot-colour variants. Our review model is a monochrome version which we paired with an Atik electronic filter wheel to take images using our 2-inch filters.

During these economically challenging times, comparing the cost of equipment to apparently similar offerings is often worthwhile. The Atik Apx26 Mono is at the higher end of the price range when compared to other cameras using the same CMOS sensor, so we were especially keen to discover what sets the Atik device apart from the competition.

Well, right out of the box, the build quality and design of the Apx26 is exemplary, with each and every facet demonstrating the high level of attention that has been given to even the smallest details. These Atik cameras have industrial applications, and in your hands they really feel like high-end, professional imaging devices, which is in fact what they are. The crossover between scientific imaging applications and long-exposure astrophotography is a happy coincidence that suits our hobby very well.

The chunky build of the Apx26 gives a reading on the scales of 1kg (without a filter wheel), so it is a reassuringly heavy camera. We paired it with our 150mm triplet refractor and the weight was useful in offsetting the hefty lens and balancing the telescope centrally on our mount, but the Apx26 can be used across a range of telescope sizes and types, with some consideration given to image scale, while binning the results 2x2 or 3x3 could provide a useful arcsecond-to-pixel ratio.

Getting started

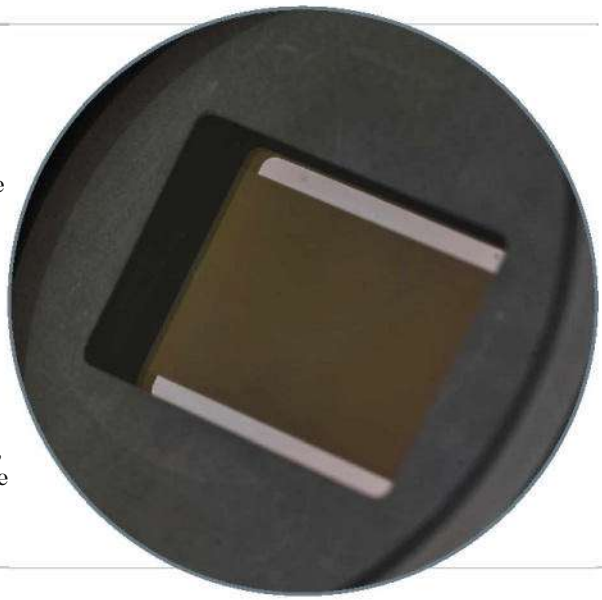
After downloading and installing the latest Atik core software bundle, it took us only a few minutes to get the camera mounted and connected to our favourite software, start up the electronic cooling and then start taking images. Atik has taken the approach of providing useful preset imaging options for the Apx26 – Low, Medium and High – which alter the gain and offset settings accordingly, with a 'Custom' tab for setting them independently.

There is also a choice of Power Save, Normal and Fast exposure speed options, but the application of these choices is not immediately obvious. We chose 'Normal' as a reasonable guess, but soon ▶

Sony IMX571 CMOS sensor

Not too long ago, discussions revolved around the superiority of old-style CCD sensors over the newer CMOS type. At the time, most were firmly in the CCD camp. However, the latest generation of back-illuminated Sony sensors has really turned things around. The IMX571 Sony sensor that forms the basis of the Apx26 is in APS-C format, giving a diagonal image area of 28.3mm. The pixel array is 6,244 x 4,168, each individual pixel being 3.76µm square. This sensor offers true 16-bit capability, which results in an enormous dynamic range, producing cameras able to simultaneously gather light from the faintest nebulae and the brightest stars without issue.

The images gathered by the Apx26 are not affected by 'amp glow' artefacts, and right out of the box, without any calibration being required, we were most impressed by the low-noise capabilities of the sensor and the hardware Atik has designed to support it. This is true even when using the high-gain setting and 15-minute exposures.



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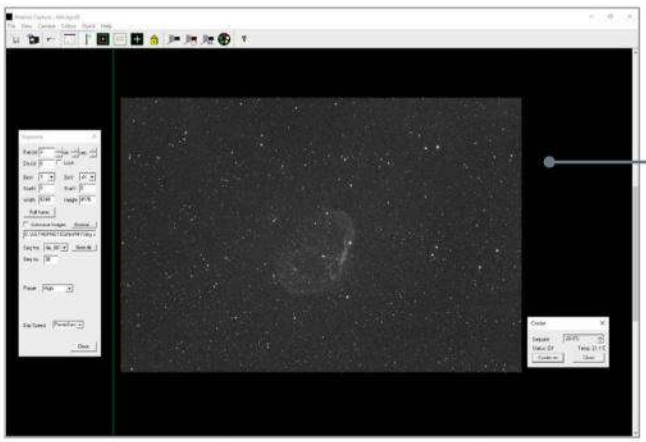


Atik software and ASCOM camera control

Atik cameras can be controlled via ASCOM protocols, so they can be used with a range of popular image-capture applications including SharpCap, SGPro and NINA. Atik's in-house Atik Capture software is also provided for full, automatic sequencing-style camera control along with auto-guiding, cooling and filter wheel control.

M54 attachment and back focus

The front of the camera has a female M54 x 0.75 thread, this wide aperture allowing vignette-free images when attaching various accessories. An M54-to-2-inch barrel adaptor is included, or direct attachment to the Atik filter wheel is possible. The back focus distance is around 17mm.

USB hub

The camera is controlled via a USB 3.0 connection for fast, stable transfer of the 26MB images, and a good-quality 2-metre cable is included. In addition, a two-port USB hub on the rear panel provides options for use with low-bandwidth accessories such as filter wheels or auto-focusers.

512MB memory buffer

Atik has always had an uncompromising approach to the internal camera design, optimising performance with low-noise electronics, and has included a 512MB memory buffer to assist with stable image transfer, avoiding dropped frames and artificial artefacts in downloaded images.

KIT TO ADD

1. Atik EFW2.2 filter wheel with 7x 36mm carousel

2. Atik 36mm unmounted LRGB and narrowband filters

3. Atik off-axis guider unit

▶ discovered (after a quick call to Atik technical support) that long exposures over 500 seconds are not possible in this mode, and that we needed to choose 'Power Save' instead. We mention this as something to factor in when choosing a camera. With Atik being a UK-based company with European production facilities, we have always found the technical support to be first-rate.

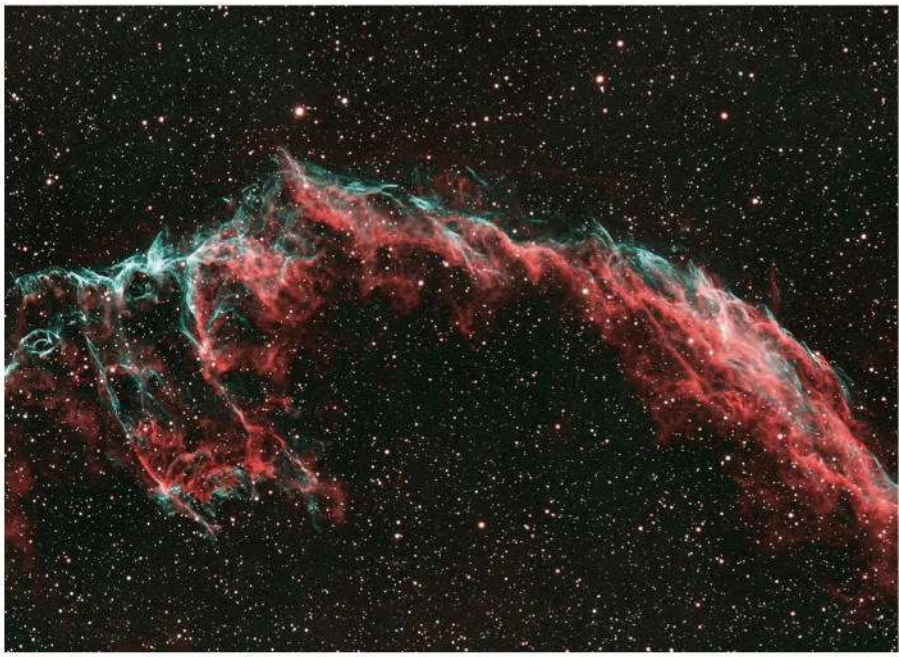
The only real issue we had during the review period was with the night sky. With a lack of astronomical darkness, we were limited to taking narrowband exposures with our H-alpha and OIII filters. The summer sky is awash with suitable targets, and we chose the Crescent Nebula (NGC 6888), the Eastern Veil Nebula (NGC 6992) and the Dumbbell Nebula (M27), as these familiar objects allowed us to compare our results from the Apx26 to previous efforts.

Finer details

We were not disappointed. The Apx26 really seemed to pull the intricate details out of the almost-twilight skies, and even the very faint outer reaches of M27, mere wispy remnants of ancient nebulosity, were faithfully gathered by the camera in just 5- to 15-minute exposures. This impressive performance with narrowband filters effectively demonstrates that the camera would be equally capable through standard RGB filters, the response through our Ha filter showing that sensitivity to light in the red range is most capable, while the OIII filter reveals the same about blue and green light. We would relish the opportunity to use this excellent camera over a season of dark skies.

Overall, the monochrome Apx26 is a premium-quality, professional astronomy camera and would make a very solid investment in the world of 16-bit CMOS astrophotography.

▲ The Apx26 did a superb job of capturing the faint outer regions of the Dumbbell Nebula, M27 from a total of 5h 25' integration time



▲ Exquisite, delicate strands in the Eastern Veil Nebula, 36x 5' exposures, 3h integration total. The Atik Apx26 was paired with a Sky-Watcher Esprit Pro 150ED, Atik filter wheel and Baader Ha and OIII filters for both of these images

Thermoelectric cooling and 12V power

The Apx26 requires a 12V DC power supply to run. A 12V cigar-lighter-type cable is supplied, but a separate PSU will be required. A powerful but quiet fan draws air over the heat sink and thermoelectrically chilled sensor. This allows the device to be cooled to 35°C below the ambient temperature.

VERDICT

Build & design	★★★★★
Connectivity	★★★★★
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★★
OVERALL	★★★★★

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Altair 70 EDQ-R f/5 quad apo astrograph

User-friendly and versatile, there's lots to love about this diminutive imaging refractor

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £1,150
- **Optics** Quadruplet design, FPL-53 glass
- **Aperture** 70mm
- **Focal length** 350mm, f/5
- **Focuser** Dual-speed rack and pinion
- **Extras** Tube rings, 245mm Vixen dovetail bar, 125mm carry handle
- **Weight** 3.8kg
- **Supplier** Altair Astro
- **Email** info@altairastro.com
- **www.** altairastro.com

ALL PICS: @THESHED/PHOTOSTUDIO

Altair Astro is no stranger to compact telescopes, with an established range of refractors offering apertures from 60mm to over 150mm. Its latest offering, the 70mm EDQ-R quadruplet astrograph, is a refractor designed with astrophotographers in mind. The ultra-portable tube is engineered to consider the needs of intermediate and advanced imagers, accommodating a variety of camera types from CCD and CMOS sensors to DSLR.

The 70 EDQ-R's four-lens optical system means you should expect pinpoint stars across an entire field of view and the focuser comes with various camera thread options, allowing the use of a range of different imaging equipment. This attention to detail lightens the accessory burden for deep-sky imagers; the extra glass in the system is specially positioned to negate the need for a field flattener, while fewer adaptors should help to simplify your imaging setup.

The 70 EDQ-R arrived well-padded in a single box, although no carry case is provided. While this would be inconvenient for longer or heavier refractors, this compact astrograph feels light and comes with a sturdy carry handle. Coupled with the tube rings and dovetail already attached, the refractor came ready to be put to use.

We were impressed with the look and finish of the optical tube assembly (OTA), which comprises beautifully machined components, no plastic and well-fitting dust caps to protect the optics. The tube comes with tube rings, adaptors and mounting options as standard, so we were confident we would be imaging with minimal setting-up time.

Smooth mover

We found the motion of the focuser to be superbly smooth, with just the right amount of resistance from the two focus knobs. The travel is far shorter than the average refractor, extending to just shy of 3cm. This is intentional to enable the quadruplet to reach infinity focus while protecting the rear lens. However, we did wonder whether we would be able to focus using both our DSLR and CCD imaging setups. Both cameras have different sensor distances, plus our ▶

Four-lens imaging system

Altair Astro's quadruplet imaging system is designed to provide high contrasts and to correct distortions such as chromatic aberrations, halos and elongated stars. The triplet FPL-53 glass lens system at the front of the tube is supported by an additional rear lens that delivers a flat field of view. As an astrograph, it acts more like a sophisticated camera lens compared with a visual telescope.

With a focal ratio of f/5, the 70mm aperture allows a respectable level of light capture, while the 350mm focal length promises flexibility for widefield imaging, meaning you can get creative with deep-sky vistas. The 70 EDQ-R collects more light in a shorter space of time than 'slower', higher-focal-ratio telescopes, which means less noise in an image. Sharper, noise-free imaging means less work in post-processing. Despite the additional glass, the 70 EDQ-R weighs in under 4kg even with accessories attached, so it's portable for those last-minute imaging opportunities.

Guide mounting options

Imaging telescopes often require further investment in hardware to mount guide equipment. Altair Astro provides much of what's needed to fit guide cameras and guidescopes to the 70mm quadruplet. There's a screw-in mount on the OTA for a guidescope, while the carry handle also doubles as a dovetail for cameras.

Tube rings and Vixen dovetail

The compact astrograph comes with a 245mm Vixen dovetail bar, making it compatible with almost all mounts. Meanwhile, the matching sturdy tube rings are fitted with large adjustment screws, which are easy to find in low light and help to balance setups if using heavier imaging equipment.

Field rotator

This easy-to-use Rotolock accessory is essential for astrophotographers. The 360° rotation allows easy reorientation of cameras without affecting focus. This capability comes in handy if adjustments to the field of view of an image are needed or if multiple narrowband filters are used during the same imaging session.

Dual-speed rack and pinion focuser

The firm but smooth movement of the focus and fine-focus knobs helps ensure precision for ultra-sharp details, while the clearly annotated tube helps users note where rough focus is achieved. Meanwhile the back end of the focuser provides thread access for M63, M54 and M48 adaptors to fit a range of cameras.

FIRST LIGHT

Retractable dew shield

The dew shield provides an ample 16.5cm of protection to the front lens and increases the compact portability of this high-performance refractor. Fully retracted, the OTA measures a mere 385mm long. Even fully extended, the tube reaches 430mm and is easy to both balance and manoeuvre in low light.

KIT TO ADD

1. Altair Hypercam 26C camera

2. Altair magnetic filter holder

3. Altair 6nm dual-band HSO filter set

▶ mono CCD has an additional filter drawer to affect spacing. Curious, we headed out to put the 70 EDQ-R to the test.

Mounting and balancing our setup was easy, thanks to the dovetail and tube rings. Starting first with our Canon 70D, we were able to obtain focus easily and a couple of test frames confirmed our stars were sharp across the full frame. We switched quickly to the narrowband and CCD setup to see if this would cause any issue for focusing. Again, we were able to resolve pin-sharp stars and so slewed over to a fluffy region of Cygnus to start shooting.

The field rotator provided on this 70mm quadruplet proved a welcome addition while switching between filters and allowed us to maintain focus throughout the night. Grabbing every last minute of the limited summer night skies, we opted for a new target, the Crescent Nebula, NGC 6888. While we didn't require spacers to achieve focus for either of our cameras, we did note that Altair has an excellent back focus diagram on their website which should provide a good guide for whether a spacer will be needed for your setup.

Processing the data the following morning revealed impressively flat and even images, confirming the astrograph performs as promised. We were left wishing we had more time with the 70 EDQ-R to really appreciate it on a dark winter night.

The four-lens system delivered pin-sharp stars in the Crescent Nebula ...

▲ ...and produced flat, high-contrast images of a 'fluffy' region in Cygnus. Both images required 70 60-second exposures in Ha and 45 in OIII, captured with a Starlight Xpress SXVR H694

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

We'd struggle to find much in the way of 'cons' for this smart 70mm quadruplet. It's easy to use and performed beautifully despite the light and humid summer night skies. The design is excellent and well thought out, while the short travel of the focuser optimises its use for astrophotography and minimises any flex in the tube that could be caused by heavy camera equipment. The 70 EDQ-R is an impressive astrograph which motivates you to head out at every clear-sky opportunity.

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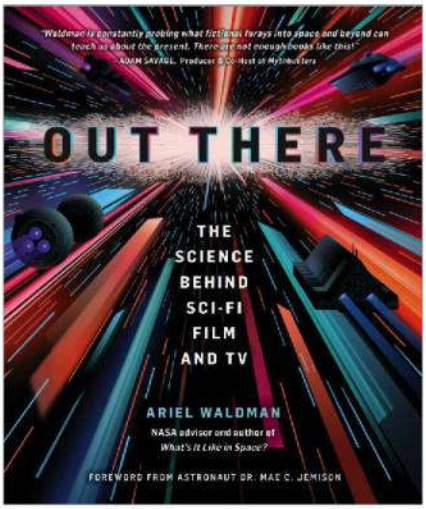
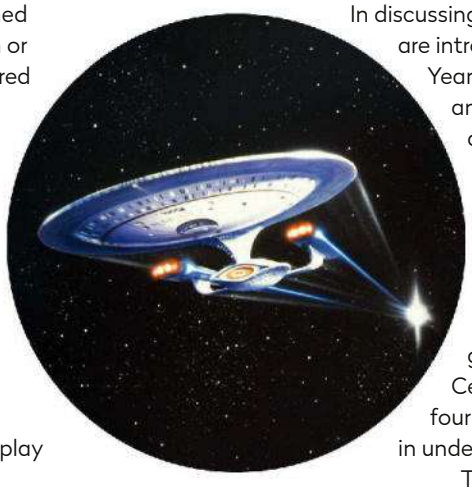

OUT THERE
THE SCIENCE BEHIND SCI-FI FILM AND TV
ARIEL WALDMAN
NASA advisor and author of What's It Like in Space?
FOREWORD FROM ASTRONAUT DR. MAE C. JEMISON

Out There: The Science Behind Sci-Fi Film and TV

Ariel Waldman
Running Press
£22 ● HB

Have you ever watched a science-fiction film or TV show and wondered whether the science depicted was possible? Could we travel at warp speed across the cosmos to engage with alien civilisations? How close are we to living on Mars? What part could cyborgs and artificial intelligence play in our future?

In *Out There*, explorer and science writer Ariel Waldman explores the common tropes, to separate science fact from fiction. Each chapter covers a single concept, discussing how it has been handled in fiction and asking experts at the forefront of their fields how close we are to achieving our aspirations.



Set phasers to stun: Waldman reveals the science facts behind our sci-fi faves

PHOTO 12/ALAMY STOCK PHOTO

A vast array of popular film and TV sci-fi is discussed, beginning with Georges Méliès's *A Trip to the Moon* in 1902, which showed Earth viewed from the Moon more than 60 years before astronauts captured the first 'Earthrise' image, and also predicted the 'splashdown' return to Earth.

We discover how astronauts, aliens, robots, artificial gravity, clones, suspended animation and starships are depicted on our screens in *Star Trek* and *Star Wars*, *Interstellar*, *Doctor Who*, *Foundation*, *The Terminator*, and many more. All the best and most popular sci-fi is drilled into.

Astronauts, astrophysicists, engineers and psychologists reveal how far science has come, and how far it has still to go. Experts take us to the cutting edge of scientific research. Discussing our exploration of other worlds, for example, we learn about the surface biosignatures of exo-Earths, a visual catalogue of spectra and pigments of the microbes that exist on Earth, that could be compared to images of exoplanets in future to determine if they are inhabited.

In discussing starships, we are introduced to the 100 Year Starship project and the research it is doing into using photons of light to propel a starship the size of your hand to 25 per cent the speed of light. This could get to Proxima Centauri, just over four lightyears away, in under 20 years.

The book is cleanly designed, the writing and the interviews are thought-provoking and all our favourite onscreen sci-fi is discussed. *Out There* is essential reading for any fan of science fiction. ★★★★★

***Jenny Winder** is an astronomy writer and broadcaster*

Interview with the author
Ariel Waldman

What was your favourite sci-fi growing up?

I grew up in a household that continuously watched *Star Trek*. It was a multi-generational thing, as even my grandfather who immigrated to the US from Iran was a *Star Trek* fan. I've had a very wayward career, starting as a graphic designer, then a digital anthropologist and citizen scientist, later advising NASA on advanced technologies and human spaceflight, and now an Antarctic explorer and filmmaker. I think *Star Trek* has inspired many generations to aspire to more interesting careers.

Does sci-fi get science right?

Like any good art, the important thing is to be intentional. In some of the most frustrating and least satisfying science fiction, creators aren't being inspired by or respectful of the actual science. Audiences can spot technobabble. It's lovely when sci-fi productions try their best to get close to the science. TV series *The Expanse* is a good example. But it's okay to push hard into fiction, so long as there's some intentionality, a system, a thoughtful approach to it.

Which concepts would you like to see become reality?

More diverse representations of everything, from asteroids to spacesuits to people in science fiction. I'd love to see the day when we confirm a second genesis of life (aka aliens), be it microscopic creatures, machines that have outlived an ancient civilisation or a signal in the electromagnetic spectrum that could only be created by intelligent life.

***Ariel Waldman** is a science communicator and former chair of NASA's Innovative Advanced Concepts advisory council*

Einstein In Time and Space

SCIENCE HISTORY

Samuel Graydon
John Murray Press
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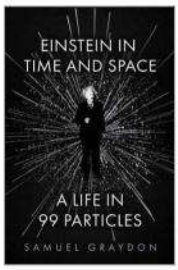


Albert Einstein is arguably the most famous scientist to have ever lived. His name is synonymous with genius, the archetypal absent-minded professor. There are a plethora of books detailing both his life and work. So what makes this book stand out? For one, it's how sympathetically he comes across.

The structure of the book – 99 short chapters, some scientific, some domestic, some anecdotal – allows his character to gradually develop over time. The snippets of information build to show how much of 20th-century physics Einstein had a part in shaping, without ever making the reader feel overwhelmed. Relativity and quantum mechanics are addressed of course, but so too is much else. The short episodic nature of this style of story-telling allows us to make up our own mind about him, and even change it. Initially he is in favour of a Jewish state and in favour of developing nuclear weapons. Later, in both cases he changes his position. At one point he seems very supportive of educated women, later much less so. To begin with, the women in his life are fellow students and scientific peers. Over time, these give way to admirers and those managing his public profile. Of all the interwoven stories, it was his relationship with his son, Eduard, that I found most troubling.

In conclusion, this is a great biography. Einstein is not treated as an unknowable genius, but as a flawed individual with interesting stories, making it an incredibly enjoyable book to read. ★★★★★

***Emily Winterburn** is a science author and astronomy historian*

All Through the Night

Dani Robertson
HarperNorth
£16.99 ● HB

Did you know that living under light-polluted skies has a negative effect on our health, wellbeing and connection with nature?

That is what Dani Robertson is determined to make the reader understand in *All Through the Night*, a passionate call to action that astronomers will welcome and non-astronomers could find illuminating (no pun intended).

The self-proclaimed "guardian of the Dark Skies" takes us through the origins of humanity's relationship with light pollution, from the invention of street lighting to our growing reliance on it – nicely detailed in the 'This Little Light of Mine' chapter – before taking us on a fascinating deep dive into the modern-day effects that we are likely unaware of.

For example, Robertson asserts that 98 per cent of people in the UK live under light-polluted skies and, because street lighting is increasing, soon the winter constellation Orion could become obscured completely. This is just one example of the sad truths she wants readers to realise, in a book where passion and urgency lie beneath poetic and whimsically written passages.

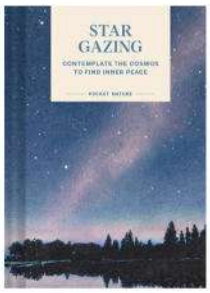
This is a window into Robertson's thoughts, ideas and frustrations. There are some points where it feels there's a sense of tunnel vision at play, which can momentarily be alienating, but her warmth and humour quickly brings our attention back to the issue at hand.

Overall, *All Through the Night* offers an articulate and impassioned argument for the preservation of our night sky, and why we should all consider paying more attention to it. ★★★★☆

***Melissa Brobby** is a science communicator and writer*

Pocket Nature: Stargazing

Swapna Krishna
Chronicle Books
£9.99 ● HB



Our busy lives often prevent us from making the time to take stock, or pausing to step outside to enjoy and appreciate the natural world. Swapna Krishna's book, *Stargazing: Contemplate the Cosmos to Find Inner Peace*, reminds us to stop and do both. The author, a science and technology writer and YouTuber, intertwines stargazing with tips for meditation under the night sky.

Simply written, this is a gentle book with an underlying theme of calm and mindfulness. Split into three sections covering a history of stargazing, understanding the night sky and constellations to look for, Krishna has chosen pertinent subjects to include over the 127 pages, including tools you may need, a seasonal constellation guide and tips on observing the Moon and planets.

Krishna makes a good point in the introduction when she says "your focus should not be on what you can't find or can't see". This is a worthwhile reminder for those beginning their stargazing journey and one, perhaps, that even the more experienced astronomers should ponder. The basic yet charming, cool, dark illustrations focus on wellbeing and beautifully complement the text. Peppered throughout are thought-provoking and inspiring quotes from astronomers and astronauts for the reader to contemplate when out under the stars.

A new addition to the Pocket Nature series, this is a delightful little hardback; factual, and easy to understand. If you are after a detailed observing guide, this is not for you, but for anyone who is perhaps going through a difficult period in life and is wishing to find peace under the night sky, this book will serve you well. ★★★★☆

***Katrin Raynor** is an astronomy writer and a fellow of the Royal Astronomical Society*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Baader MaxBright II binoviewer

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2 Omegon Mount MiniTrack LX Quattro

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www.astroshop.eu

This mini astrophotography mount operates by clockwork, meaning it can provide up to 60 minutes of tracking without the need for power. This new version supports cameras and lenses up to 4kg in weight with incredible smoothness and precision.

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Stay warm throughout a night's observing with a mug of your favourite hot drink that's being kept toasty in this travel mug. It has a generous 420ml capacity and a slide locking lid to prevent spillages.

4 Science Mad planetarium star globe

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Turn down the lights to see the constellations glow from this illuminated planetarium. The globe slowly rotates, showing off the sky's most famous constellations, each of which is clearly labelled to help little astronomers learn their star patterns.

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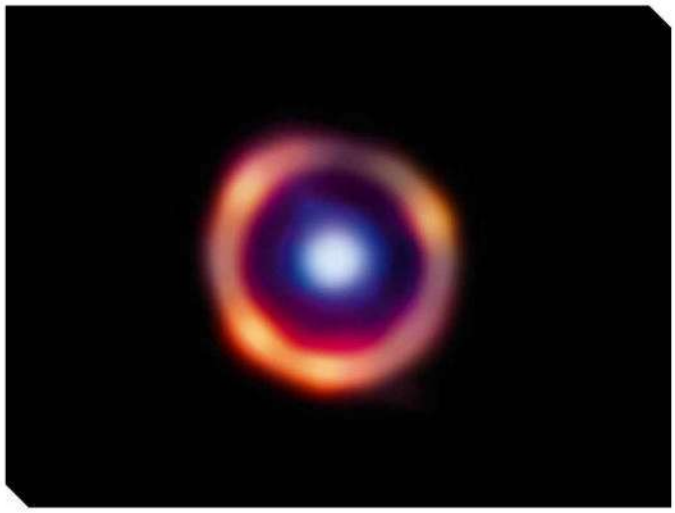
Anita Chandran interviews Professor Justin Spilker

Q&A WITH A GALACTIC GAS INVESTIGATOR

Big, complex organic molecules – the building blocks of life – have been found in the most distant galaxies yet, only 1.5 billion years after the Big Bang

What did your investigation involve?
We were looking for complex organic molecules called polycyclic aromatic hydrocarbons or PAHs. On Earth, they show up in smoke and smog, but they also form naturally in space. Using the James Webb Space Telescope (JWST), we were trying to set the record for the farthest-away galaxy in which we could see PAHs. We were looking at a very distant galaxy, SPT0418-47, which corresponds to looking very far back in time (because it takes time for light to travel to us). The light that JWST found has been travelling to us steadily for 12 billion years. When looking at this light, we spotted these molecules.



▲ **SPT0418-47, the galaxy 12 billion lightyears away where Professor Spilker and colleagues detected the chemicals similar to those that sparked life on Earth**

Why were you looking for PAHs?
Because they're big molecules, as far as space goes. A molecule like water has three atoms: two hydrogens and an oxygen. PAHs can have hundreds of atoms in them, and so they're about as complex as molecules in space can get.

What can PAHs tell you?
They could tell us about how fast galaxies are making new stars, because they get brighter if a galaxy has been forming stars recently. Stars like our Sun are relatively small, but there are much bigger, brighter stars that burn much hotter than our Sun. When these stars burn, they give off huge amounts of ultraviolet light.

These organic molecules we found can absorb that ultraviolet light and then glow, giving off infrared light. JWST is an infrared telescope so it doesn't necessarily look for light that our eyes can see. We used its Mid-Infrared Instrument to split up light coming from one of these distant galaxies into its different infrared colours to look for the fingerprint of these complex molecules.

Isn't the light that comes from a distant galaxy very faint?
JWST is able to look at very faint objects and so is naturally great at studying the very early Universe. But the galaxy we discovered these molecules in is also very bright in infrared light. Astronomers have discovered that this galaxy is not one but two galaxies that are almost perfectly aligned when looked at from Earth. If you have that configuration, the light from the background galaxy gets magnified as it travels around the galaxy in front. We call this 'gravitational lensing' and it makes the background galaxy appear bigger and brighter than it actually is, in this case by a factor of about 30. That enables us to study it in detail.

What can we learn about early stars and their growth from PAHs?
We had believed that these molecules should tell us where the biggest and baddest stars are forming: 'smoke' where there's 'fire'. But we actually found there are some places in this galaxy where there are PAHs but no young stars (smoke but no fire), and some with stars forming but no PAHs (fire but no smoke). We don't yet know what's causing that. This is the start of the road as opposed to the end, in terms of understanding what these molecules can tell us. This was the first time that we'd seen them in such a distant galaxy, and we have a lot more work to do.

What does your discovery mean for future observations?
There are several campaigns going on with the JWST and other telescopes to try to start understanding these big, complex organic molecules in galaxies. Having found them in the most distant galaxy yet, maybe we can go to even earlier in the Universe's history. The galaxy we studied lived when the Universe was about 1.5 billion years old. How early can we go before these molecules stop existing? A billion years? Eight hundred million?

The goal is to try to understand where, when and how stars are forming in these galaxies. We want to use PAHs to tell us about how fast a galaxy is forming stars, and look forward to figuring out how PAHs stack up to other techniques astronomers use to understand star formation.

Justin Spilker is an assistant professor of astronomy at Texas A&M University, specialising in the formation and evolution of galaxies throughout the Universe's history

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Discover targets around the bright constellation of Grus the Crane and watch for favourable Orionids

When to use this chart

1 Oct at 00:00 AEST (14:00 UT)
15 Oct at 23:00 AEDT (12:00 UT)
31 Oct at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

OCTOBER HIGHLIGHTS

The Orionids meteor shower is visible around 2 October to 7 November, with its peak expected late evening on 22 October into the morning. At this time the Moon is at first quarter, leaving the morning hours basking under dark skies. The radiant is within a few degrees of the bright star Betelgeuse. This area will be conveniently high in the sky (crossing the meridian) around the start of dawn. The Orionids are typically swift and often bright, with some leaving trains.

STARS AND CONSTELLATIONS

Evening skies now see the Milky Way dropping towards the western horizon, making way for, well... nothing? That's how it appears from the suburbs. The far south has not only left the bright star patterns behind, but also Greek mythology has given way to more modern constellations. Many need dark skies to see any patterns, Grus the Crane being one bright exception. Other birds to spot are the Peacock (Pavo), the Toucan (Tucana) and, albeit mythical, the Phoenix.

THE PLANETS

Saturn continues to be an evening highlight, being due north around 22:00 mid-month. Although in a barren part of the sky, it sits about 20° south of the bright star Fomalhaut. It's followed two hours later by Neptune. Jupiter is rising around sunset, with Uranus 30 minutes behind. Both are visible most of the night. Dawn commences with brilliant Venus low in the east. On the 11th, Venus and Regulus are 2° apart, with the crescent Moon 5° below – an impressive conjunction!

DEEP-SKY OBJECTS

This month, a trip to Grus the Crane. Within its prominent curve of stars is an impressive naked-eye double-double. Delta (δ) Gruis (RA 22h 29.2m, dec. −43° 30') comprises mag. +4.0 and +4.1 Delta[1] (δ[1]) and Delta[2] (δ[2]), 16 arcminutes apart. Moving 3° northwest finds Mu (μ) Gruis, comprised of mag. +4.8 Mu[1] (μ[1]) and +5.1 Mu[2] (μ[2]), 19 arcminutes apart. In binoculars both Mu stars and Delta[1] are yellow, in contrast to the orange of Delta[2].

NGC 7582 (RA 23h 18.4m, dec. −42° 22') is the central member of the Grus Quartet, an 11th-magnitude triangle of galaxies with NGC 7590 and 7599 (to the northeast), fitting in a 15-arcminute field of view. The three are all partly edge-on spirals, showing prominent ellipse-shaped halos with brightening towards the centre. Lying 30 arcminutes southwest of 7582 is the fourth member, NGC 7552, which has a prominent stellar nucleus.

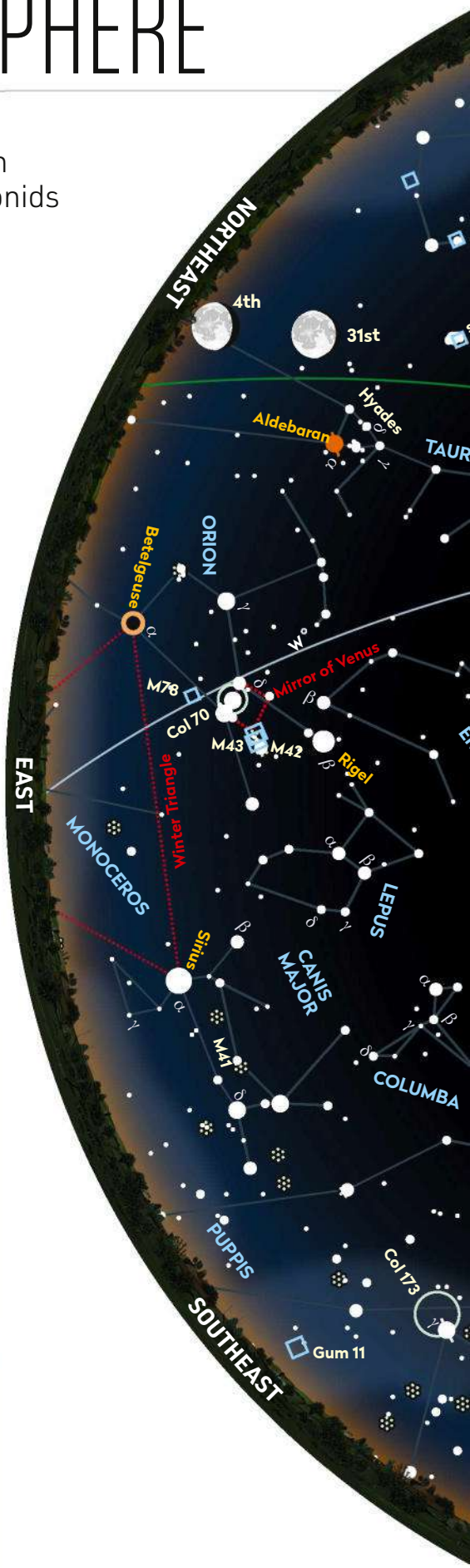

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
PERSEUS
Mel 20
Algol
M34
ANDROMEDA
M31
M110
M32
NGC 7686
Blue Snowball
LACERTA
CYGNUS
Veil Nebula
Dumbbell
Summer Triangle
TRIANGULUM
NGC 752
M33
Alpheratz
PEGASUS
Great Square of Pegasus
Pleiades
ARIES
1st
Ecliptic
Uranus
Jupiter
28th
PISCES
Menkar
Circlet
Enif
M15
EQUULEUS
DELPHINUS
SAGITTA
AQUILA
Altair
Water Jar
M2
SERPENS CAUDA
Celestial Equator
CETUS
Neptune
25th
AQUARIUS
Saturn
Saturn Nebula
Deneb Kaitos
NGC 253
ERIDANUS
FORNAX
Fomalhaut
Helix Nebula
SCULPTOR
PISCIS AUSTRINUS
CAPRICORNUS
NGC 7590
NGC 7552
PHOENIX
NGC 7599
NGC 7582
GRUS
22nd
Pluto
SAGITTARIUS
SCUTUM
M11
M25
M16
M17
CAELUM
HOROLOGIUM
MICROSCOPIUM
INDUS
M55
M22
M28
M21
M8
M20
Teapot
DORADO
RETICULUM
Achernar
TUCANA
47 Tucanae
Tarantula Nebula
SMC
HYDRUS
CORONA AUSTRALIS
PICTOR
Canopus
LMC
MENSA
OCTANS
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